Chinook Salmon (*Oncorhynchus tshawytscha*) Scale Age Determination Procedures

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ABSTRACT

MacLellan, S.E., and Gillespie, D.C. 2015. Chinook salmon (*Onchorhynchus tshawytscha)* scale age determination procedures. Can.Tech. Rep. Fish. Aquat. Sci.3123: iv + 69 p.

This manual describes standard protocols used by the Department of Fisheries and Oceans (DFO) Sclerochronology Lab program at the Pacific Biological Station in Nanaimo, B.C. to determine the age of scales sampled from Chinook salmon (*Onchorhynchus tshawytscha*) captured in Canadian fisheries. Production of best quality age data is dependent on consistent and correct application of method criteria. The manual sets out procedures which have evolved and were developed to be the current operational standards for the DFO Pacific Region. A further purpose is to provide information to other agencies and individuals wishing to employ established scale ageing methods for age determination of Chinook. A series of photos depicting examples of scale growth patterns and their age are included from representative stocks in various regions of B.C.

RESUMÉ

MacLellan, S.E. et Gillespie, D.C. 2015. Procédures de déterminations de l'âge des écailles de saumon quinnat (*Onchorhynchus tshawytscha)*. Rapp. tech. can. sci. halieut. 3123: iv + 69 p.

Ce manuel décrit les protocoles normalisés utilisés par le programme du laboratoire sclérochronologique du ministère des Pêches et des Océans (MPO) à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique, afin de déterminer l'âge des écailles prélevées sur des saumons quinnat (*Onchorhynchus tshawytscha*) capturés dans le cadre des pêches canadiennes. Pour produire des données sur l'âge de la meilleure qualité, il faut appliquer correctement et uniformément les critères et la méthode. Le manuel décrit les procédures modifiées et élaborées pour devenir les normes opérationnelles actuelles en vigueur dans la région du Pacifique du MPO. Le manuel vise également à fournir de l'information à d'autres organismes et personnes qui souhaitent utiliser des méthodes éprouvées de détermination de l'âge des écailles pour déterminer l'âge des saumons quinnat. Une série de photos illustrant des exemples de profils de croissance des écailles et leur âge, tirés de stocks représentatifs des diverses régions de la Colombie-Britannique, est incluse.

INTRODUCTION

This manual describes policies and procedures employed by the Fisheries and Oceans Canada Sclerochronology Laboratory (SCL) program at the Pacific Biological Station in Nanaimo, B.C. for salmon age determination activities. It includes conventions applied to facilitate production of precise and accurate age data for stock assessment and focuses on Chinook (*Oncorhynchus tshawytscha)* scale age determination. Fin cross-section and otolith methods are used to age a small number of salmon stocks but are not included in this document. Readers should note that descriptions of procedures make use of specific standard terminology for which definitions can be found in the glossary near the back.

The prime mandate of the SCL program is to provide good quality age data and advice regarding age determination activities to DFO in the Pacific region. This includes British Columbia and the Yukon. The SCL is a central depot for samples originating from commercial, sport and Aboriginal fisheries, hatcheries and scientific surveys. Age data contributes to the understanding of fish biology and the health of stocks. Salmon age data is primarily used for stock assessment and influences decisions on whether to open, close and extend fisheries. In the last 10 years the SCL has provided age data for approximately 80,000 Chinook (*O. tshawytscha*), Sockeye (*O. nerka*), Coho (*O. kisutch*) and Chum (*O. keta*) salmon annually. Fraser River Sockeye and Pink (*O. gorbuscha*) are excluded as these stocks are the mandate of the Pacific Salmon Commission. Table 1 lists the numbers of each salmon species aged by the SCL from 1990 to 2014. Since 1990 the SCL has aged 1,730,563 salmon (4 species) of which 639,647 were Chinook.

Table 1. Numbers of each salmon species aged by the SCL from 1990 to 2014.

Species	# Fish
Chinook	639,647
Chum	287,708
Coho	230,869
Sockeye/Kokanee	572,339
Total	1,730,563

QUALITY ASSURANCE SYSTEM

Most of the SCL's activities operate within a Quality Assurance (QA) system. It consists of planned, documented and systematic methods and procedures to demonstrate confidence in the age data quality and/or to confirm that the data conforms to specified requirements. Quality Control (QC) is part of the QA system and is the responsibility of everyone in the program. QC is a specific process to test results against set standards and the actions taken when there are discrepancies.

Although focused on production ageing, the SCL spends about 20% of its time working on projects to develop new methods or standards for age determination, quality control,

method validation and data management. The program is age data centric working to build and maintain a deep and broad pool of expertise in the field of fisheries age determination. The SCL has no stake in the age data they create other than to produce the best quality possible. Campana (2001) provides a thorough review of the importance of accuracy, precision and quality control for age determination.

More often than not, data users and clients are only interested in the final ages without a concern for how the ages are derived. It is essential that age data production and subsequent use of the data be a collaborative effort between age readers and clients. The SCL documents age data issues to forward to data users. Clients are responsible for understanding the quality and limitations of the age data they use for stock assessments (Beamish and McFarlane 1983). In return, the SCL encourages feedback to help improve data quality.

Protocols and standards have evolved over time and have been established as part of the SCL's QA system and routine work culture. Establishing standard practices has promoted data continuity and precision (consistency) and has enhanced accuracy (closeness to true age) over the long term. This includes use of standard high quality equipment, ergonomics, reference materials, training systems, production ageing procedures and age determination methods that include specific criteria.

1. Equipment and ergonomic standards

Standard, equivalent state-of-the-art equipment with specialized ergonomic parts and best quality optics and lighting, are available to each SCL reader. If readers cannot "see" the same quality scale image they will not produce similar age estimates. Standard equipment facilitates consistent and accurate interpretation of growth patterns. Age determination involves long hours of repetitive work at a microscope which can lead to repetitive-use injuries. Ergonomic workstations ensure the physical health of readers who possess unique and difficult to learn skills and retain long-term employees.

a) Equipment

Figure 1 shows the equipment used by SCL staff to produce quality salmon scale impressions (Hudson and Crosby 2010) and to age and photograph scales. The majority of SCL salmon scale samples are aged using 4 Neopromar projectors that produce very large clear images of scale acetate impressions.

- Geo-Knight DK20SP scale press (Fig. 1a).
- Leitz Neopromar projectors (magnification 10-40X) produce a large clear image for salmon scale age determination (Fig.1b). These are the SCL's preferred scope for age determination of salmon scales.
- Leica MZ7.5 dissecting microscope with transmitted light base with KL2500 LCD fibre optic light source (Fig. 1c). Lighted bases are used in conjunction with

transmitted light to age some salmon scales with less complex patterns (e.g. Chum and Coho stocks) when all Neopromars are in use.

- Leica DFC295 camera and M205C stereo-microscope system (Fig. 1d) or the Leica DM2000 compound microscope with DFC320 camera are 2 setups used to photograph salmon scales. Both use the Leica Application Suite (LAS) version 4.4 or Image-Pro Premier 9.1 software to take digital images for documentation, demonstration and publication.

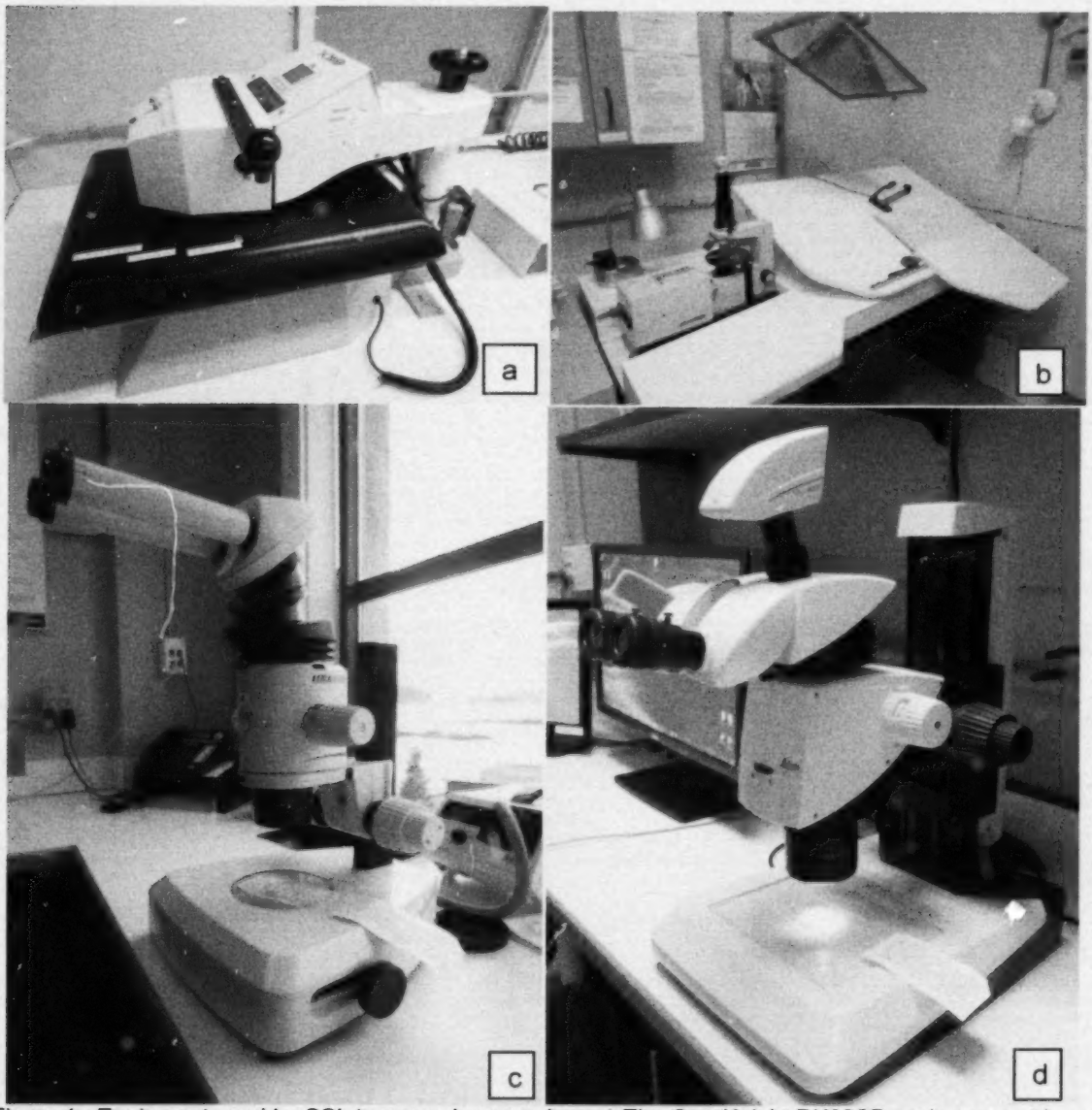


Figure 1. Equipment used by SCL to age salmon scales. a) The Geo-Knight DK20SP scale press. b) Neopromar projector and ergonomic workstation. c) Leica MZ7.5 dissecting scope with transmitted light base with KL2500 LCD fibre optic light source. d) Leica DFC295 camera and M205C stereo-microscope system.

b) Ergonomics

Proper ergonomic workstations in the SCL have been a good investment for staff retention. The SCL consulted Federal, Provincial, as well private consultants over time to develop ergonomic standards. The program strives to ensure that all equipment and workstations can safely be used by all staff without incurring repetitive injuries. Specialized equipment, ergonomic parts and setup have been researched to accommodate various "sized" people to work comfortably and safely, especially for shared workstations. If workstations are not adjustable injuries to the legs, back, neck, wrists and hands may occur over the long-term. This can compromise age data quality and lead to lost time and expertise impacting capacity.

SCL salmon scale workstation ergonomics:

1. Adjustable eyepieces for focus and inter-pupillary distance to avoid eye strain.
2. Tilt-able scope heads and desktops to ensure straight ahead vision to prevent neck strain.
3. Scope height controls to adjust to different heights and promote good posture (sitting with a straight back and neck).
4. Coarse and fine focus knobs to avoid thumb and wrist problems.
5. Focus controls close to counter to avoid elbow pressure points and allow wrists to be kept as straight as possible.
6. Rounded counter edges to avoid pressure ridges on arms.
7. High-backed chairs with adjustable seat tilt and height, back tilt and adjustable arms to provide good support to back, shoulders and arms while promoting good posture.
8. Document holders to avoid neck strain.
9. Foam wedge supports for forearm and wrist while operating Neopromar projectors.

2. Reference material

The SCL uses written materials, photographs and specific physical samples as references. They facilitate training, help maintain age data quality, enhance demonstration, contribute to publications and help avoid reader drift. Reader drift usually occurs when readers unknowingly change how method criteria are applied. This can happen over a long period of time with one reader or quite suddenly when new readers come on board. Reader drift can have profound effects on stock assessment analysis. Documentation is a regular part of SCL activities and all staff are expected to participate.

a) Written documentation

Over time age determination methods and criteria used by the SCL have gone through purposeful updating or changes. These needed to be explained and discussed with data users and had to be thoroughly documented in writing. Written documentation is a strong tool that helps to avoid reader drift. After each salmon sample is aged the SCL first readers add to the cumulative information for each stock in a living Word document that exists on a shared network drive (see example below). SCL salmon readers review

this information each time before they age any Chinook scale samples from a particular stock or location.

Example of Word documentation sequence written for Chinook salmon scale samples aged over a period of years:

Atnarko Mark Recapture Program:

2009 fish were sampled Sept 9 – Oct 8. The majority were aged 0.3 along with some 0.2, 0.4, 0.5, and some 1.3 & 1.2. All scales were resorbed and a year was added when the + growth was 2 or more. Note: *The resorbed scale criteria for Atnarko was changed this year (see below), this change was supported by CWT ages. **Scales with + growth of 1² or less remained the same age, those with 2' growth were given only a FW age and a year was added to scales with ≥2 + growth.*
09/12/23 DL/KC/DG

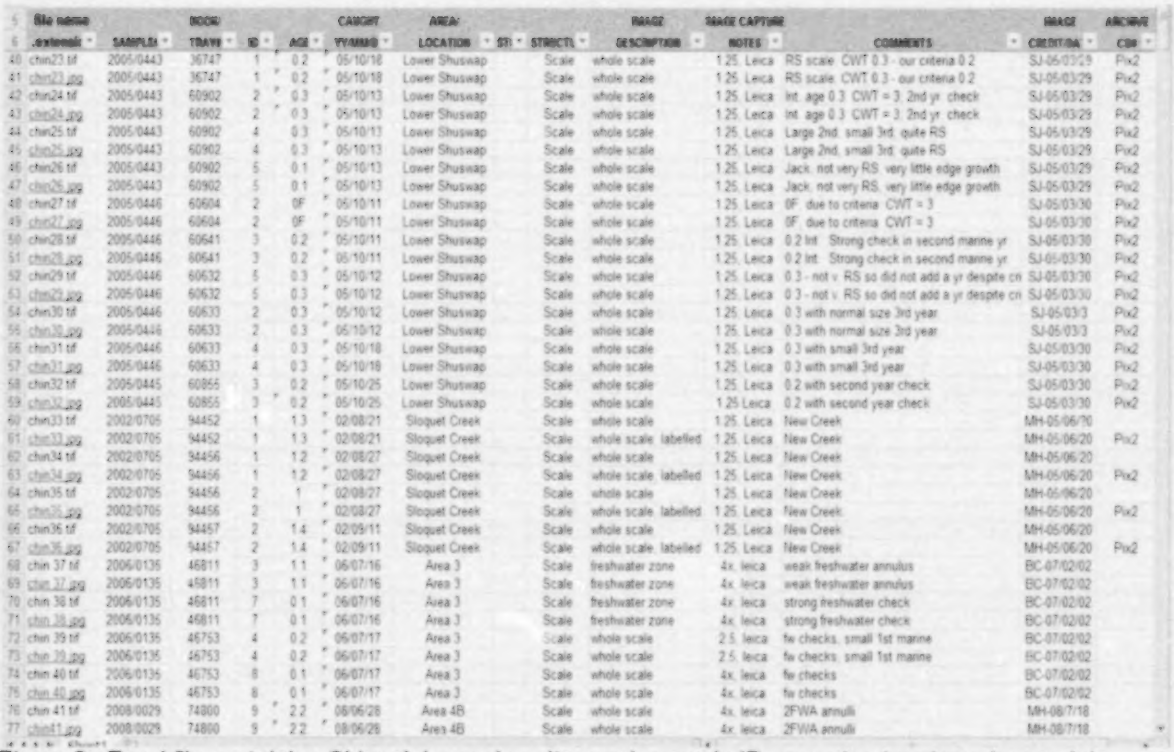
2010 Atnarko Mark Recapture samples were collected Sep 14-30. Scales were about 2/3rds 0FWA and 1/3rd 1FWA. There were many 0FWA with very strong Transition check (TC) that didn't look strong in the posterior and the circuli in the 1st SW year were fairly regular and even in formation. Usually the FWA were quite distinct. The sample was overall fairly resorbed but was also very Wet with lots of regenerate and some upside down scales. I used the Resorption criteria from 2009 samples. 11/02/25 SEM

Precision results were fairly good at 87% agreement. However, comparison of scale age to CWT age in samples was 73% agreement. Most differences were due to assigning a FWA when the CWT indicated it would be a check (due to total CWT age) and the other difference would be that the scales were under-aged due to resorption. Looked at all CWT differences and took some photos to show the FW growth patterns that are occurring and how prominent the FW transition check can be vs. what a 1FW looks like in the Atnarko. Generally feel that the 1FW fish have very tight, closely spaced FW circuli (cutout) with breaking and pinching circuli and a larger 1st SW year. With 0FW fish, the 1st SW year tends to be smaller or about the same size as the 2nd SW year and the circuli are more closely spaced than in the 2nd SW year. In a 0FW fish, the circuli after the focus can be wide with just a few closely spaced circuli near the end of FW with less pinching and breaking at the posterior margin (cap).
(11/03/03 DG)

..\..\..\..\Images\Salmon\Chinook\chin119.jpg ..\..\..\..\Images\Salmon\Chinook\chin120.jpg
..\..\..\..\Images\Salmon\Chinook\chin122.jpg ..\..\..\..\Images\Salmon\Chinook\chin123.jpg
..\..\..\..\Images\Salmon\Chinook\chin124.jpg ..\..\..\..\Images\Salmon\Chinook\chin125.jpg"

b) Image documentation

Photographic documentation is a very effective tool to ensure that methods and criteria remain consistent over time. Age determination is a visual pattern recognition skill where a picture truly is worth a thousand words. The SCL has standard protocols for capturing and annotating digital images. All readers are expected to contribute to the photographic archives. The readers in a team identify scales to be photographed as they age samples. Digital images are stored on the shared network drive for all staff to access. An Excel image log documents photos for each species (Fig. 2). In some cases images will be linked (see above) to the Word document that describes samples and ageing issues.



	File name		BOOK			CAUGHT	AREA			IMAGE	IMAGE CAPTURE		IMAGE	ARCHIVE
	.extensio	SAMPLE	TRAY#	ID	AGE	YY/MM/D	LOCATION	ST	STRUCTU	DESCRIPTION	NOTES	COMMENTS	CREDIT/DA	CD#
40	chin23.tif	2005/0443	36747	1	0.2	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	RS scale. CWT 0.3 - our criteria 0.2	SJ-05/03/29	Pix2
41	chin23.jpg	2005/0443	36747	1	0.2	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	RS scale. CWT 0.3 - our criteria 0.2	SJ-05/03/29	Pix2
42	chin24.tif	2005/0443	60902	2	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Int. age 0.3. CWT = 3. 2nd yr. check	SJ-05/03/29	Pix2
43	chin24.jpg	2005/0443	60902	2	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Int. age 0.3. CWT = 3. 2nd yr. check	SJ-05/03/29	Pix2
44	chin25.tif	2005/0443	60902	4	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Large 2nd, small 3rd, quite RS	SJ-05/03/29	Pix2
45	chin25.jpg	2005/0443	60902	4	0.3	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Large 2nd, small 3rd, quite RS	SJ-05/03/29	Pix2
46	chin26.tif	2005/0443	60902	5	0.1	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Jack, not very RS, very little edge growth	SJ-05/03/29	Pix2
47	chin26.jpg	2005/0443	60902	5	0.1	05/10/13	Lower Shuswap		Scale	whole scale	1.25, Leica	Jack, not very RS, very little edge growth	SJ-05/03/29	Pix2
48	chin27.tif	2005/0446	60604	2	0F	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0F, due to criteria, CWT = 3	SJ-05/03/30	Pix2
49	chin27.jpg	2005/0446	60604	2	0F	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0F, due to criteria, CWT = 3	SJ-05/03/30	Pix2
50	chin28.tif	2005/0446	60641	3	0.2	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 Int. Strong check in second marine yr	SJ-05/03/30	Pix2
51	chin28.jpg	2005/0446	60641	3	0.2	05/10/11	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 Int. Strong check in second marine yr	SJ-05/03/30	Pix2
52	chin29.tif	2005/0446	60632	5	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 - not v. RS so did not add a yr despite cri	SJ-05/03/30	Pix2
53	chin29.jpg	2005/0446	60632	5	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 - not v. RS so did not add a yr despite cri	SJ-05/03/30	Pix2
54	chin30.tif	2005/0446	60633	2	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with normal size 3rd year	SJ-05/03/3	Pix2
55	chin30.jpg	2005/0446	60633	2	0.3	05/10/12	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with normal size 3rd year	SJ-05/03/3	Pix2
56	chin31.tif	2005/0446	60633	4	0.3	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with small 3rd year	SJ-05/03/30	Pix2
57	chin31.jpg	2005/0446	60633	4	0.3	05/10/18	Lower Shuswap		Scale	whole scale	1.25, Leica	0.3 with small 3rd year	SJ-05/03/30	Pix2
58	chin32.tif	2005/0445	60866	3	0.2	05/10/25	Lower Shuswap		Scale	whole scale	1.25, Leica	0.2 with second year check	SJ-05/03/30	Pix2
59	chin32.jpg	2005/0445	60866	3	0.2	05/10/25	Lower Shuswap		Scale	whole scale	1.25 Leica	0.2 with second year check	SJ-05/03/30	Pix2
60	chin33.tif	2002/0705	94452	1	1.3	02/08/21	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
61	chin33.jpg	2002/0705	94452	1	1.3	02/08/21	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
62	chin34.tif	2002/0705	94456	1	1.2	02/08/27	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
63	chin34.jpg	2002/0705	94456	1	1.2	02/08/27	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
64	chin35.tif	2002/0705	94456	2	1	02/08/27	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
65	chin35.jpg	2002/0705	94456	2	1	02/08/27	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
66	chin36.tif	2002/0705	94457	2	1.4	02/09/11	Sloquet Creek		Scale	whole scale	1.25, Leica	New Creek	MH-05/06/20	
67	chin36.jpg	2002/0705	94457	2	1.4	02/09/11	Sloquet Creek		Scale	whole scale, labelled	1.25, Leica	New Creek	MH-05/06/20	Pix2
68	chin 37.tif	2006/0135	46811	3	1.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	weak freshwater annulus	BC-07/02/02	
69	chin 37.jpg	2006/0135	46811	3	1.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	weak freshwater annulus	BC-07/02/02	
70	chin 38.tif	2006/0135	46811	7	0.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	strong freshwater check	BC-07/02/02	
71	chin 38.jpg	2006/0135	46811	7	0.1	06/07/16	Area 3		Scale	freshwater zone	4x, leica	strong freshwater check	BC-07/02/02	
72	chin 39.tif	2006/0135	46753	4	0.2	06/07/17	Area 3		Scale	whole scale	2.5, leica	fw checks, small 1st marine	BC-07/02/02	
73	chin 39.jpg	2006/0135	46753	4	0.2	06/07/17	Area 3		Scale	whole scale	2.5, leica	fw checks, small 1st marine	BC-07/02/02	
74	chin 40.tif	2006/0135	46753	8	0.1	06/07/17	Area 3		Scale	whole scale	4x, leica	fw checks	BC-07/02/02	
75	chin 40.jpg	2006/0135	46753	8	0.1	06/07/17	Area 3		Scale	whole scale	4x, leica	fw checks	BC-07/02/02	
76	chin 41.tif	2008/0029	74800	9	2.2	08/06/28	Area 4B		Scale	whole scale	4x, leica	2FWA annuli	MH-08/7/18	
77	chin41.jpg	2008/0029	74800	9	2.2	08/06/28	Area 4B		Scale	whole scale	4x, leica	2FWA annuli	MH-08/7/18	

Figure 2. Excel file containing Chinook image log. It records sample ID, age, structure type, image data as well as the reason for taking a photo.

c) Reference collections:

To avoid reader drift, some fisheries agencies prefer to assemble and maintain permanent or semi-permanent age sample reference collections for training and testing. These may or may not be known-age. Known-age samples are a QC tool utilized by the SCL to validate age data and methods whenever possible. These opportunities are generally rare for most species, however salmon are the exception.

Reference collections have their place, but they work best for labs with one to a few readers and or when numbers of species/stocks aged are small. The SCL employs 9-10 readers and production-ages a large number of groundfish species (>40), two shellfish species, several herring stocks and four salmon species consisting of 100's of stocks on an annual basis. Although the program assembled some reference collections years ago, it took an enormous amount of effort to do so and the labour to maintain them was significant, impacting production. Instead, the SCL relies more on published and unpublished documentation (manuals and reports with photos) and established QA/QC standards and procedures, including use of coded wire tags (CWT) from known-age salmon and documented past-aged samples as references to help ward off reader drift. Rather than maintaining specific formal reference collections, the SCL relies on demonstrative past/recently aged samples for training and testing.

3. Training and development system

The training and development policy of the SCL is intended to expand and preserve its expertise against loss through retirement and unforeseen events. The work culture of the program is unique, complex and dynamic. It takes several years for a newcomer to absorb it all. SCL readers eventually learn how to age all species using all methods employed by the program. To continue development, readers must demonstrate that they can maintain the designated level of expertise required to age the species they are already trained in over the long term. Depending on need and other duties, it generally takes 2-3 years for a novice SCL reader to be trained to age all Chinook stocks and life history type samples sent to the program.

The SCL provides age data for hundreds of Chinook stocks (Holtby and Ciruna 2007) from B.C. and Yukon waters. It takes a number of years and review of thousands of scales to accumulate both broad and deep coast-wide expertise required to age all stocks. Acceptable deep expertise for certain stocks can be picked up in one to two seasons (years) by ageing in the range of hundreds to low thousands of fish. To gain broad expertise takes several seasons. The Chinook reader needs to review many thousands of samples representing all stocks and life histories to achieve good broad experience in the SCL. A broad level of experience (coast-wide) is needed before participating in age determination of mixed fishery samples (McNicol and MacLellan 2010). Although not the easiest salmon species to start with, Chinook are often used to train novices as large numbers of samples are readily available throughout the year. Training begins with escapement samples with little scale resorption. There is an extensive learning curve regarding the consistent and accurate interpretation of freshwater growth.

Any skilled and experienced Chinook reader in the SCL may be asked to train others. They are chosen according to their demonstrated abilities, experience and in regards to their availability within the program's work schedule. Good coaching skills are important. The trainer is responsible for developing a written training plan with input from the student and is subject to the supervisor's approval. The trainer's task is to follow through with the process according to set policies and procedures and to objectively assess the student's progress and skill levels. A training plan (see end of this section) provides a step by step reference with clear goals and expectations for both the trainer and student. If progress does not go as expected it is up to the trainer to investigate and work with the student to overcome problems. It is equally important for the student to indicate when they need help to ensure that they achieve the expected goals.

The SCL assesses two key technical competencies, quality and quantity, to measure a student's age determination skills. The first is imperative while the second is necessary. Both are measured against standard target values. Quality is assessed by measuring precision and accuracy. Productivity is measured against established productivity target rates (#fish aged/hour). Both competencies are important to develop and assess in stages by the trainer.

Comparative tests against self, experienced readers and Coded Wire Tagged (CWT) fish samples are used to assess a student's precision and accuracy to identify biases so that adjustments can be made with further coaching. Students learning to age Chinook scales are expected to meet agreement targets of 80% and do so for both difficult as well as easy to age samples to be designated an expert. Progress and results are collated in an Excel training form (Fig. 3). Students must also learn to eventually meet productivity targets. The SCL is responsible for ageing >70,000-80,000 salmon a year plus herring, groundfish and shellfish. Students must learn to age swiftly with certainty. In order to become an expert reader a novice must develop good judgment and decisiveness so as not to spend too much time agonizing over the age assessment of a single fish. They need to know the limits of the methods and criteria they are employing.

Training requires a considerable effort. While teaching, the trainer's participation in production ageing and other regular duties are impacted, lowering SCL capacity. Training, especially novices, must be very carefully planned into the annual work schedule in order to ensure that all the region's priority age requests can be met on time. There is a limit to how much time and effort can be invested in training any one person. Not all people have the disposition and the skill-set suited for this meticulous yet fast-paced unique work. If a novice cannot establish technical competencies within the framework of the training plan they do not possess the ability required to work in the program.

Novice Chinook reader training plan:

Goal: First, to participate in production scale ageing and gain deep experience determining the age of Chinook stocks with simple life histories and little/no scale resorption (stages 1-3). With additional training, broaden expertise by learning to age a wide variety of Chinook stocks and life history types including those with extensive resorption (stage 4).

Expectations:

By end of training students must consistently demonstrate they can meet a minimum precision target of 80% or better with themselves and expert readers to begin participating in routine production ageing. Historically, SCL Chinook scale readers have produced agreement of 90% or better with self and other experienced readers. This usually requires reviewing/ageing scales from about 1,200-1,500 fish. A productivity target of 40-80 fish/hr (average 60 fish/hr) with 5 scale/fish samples is expected to be achieved with time. Expert status is achieved when quality and quantity targets are met and maintained with difficult (ocean- and stream-type and resorbed scales) as well as easy samples. An SCL reader is expected to maintain, broaden and deepen expertise in a wide range of B.C. stocks and life history types over the long term (over years) as required.

Stage 1:

- The student will review scales from 400-500 Chinook (first with the trainer and then on their own), to become familiar with the scope of growth pattern characteristics and their variations. For example, Nass River (North coast) and Vancouver Island (South coast) stocks where only one life history type occur within a system and scale resorption is not an issue.
- The goal is to be able to produce ages similar to those of an experienced reader and be consistent with themselves, most of the time, while looking at previously aged samples and having access to age data. Similar means generating the same age types 60-70% of the time.
- Once confident with recognising and interpreting these patterns, the student will age approximately 400-500 additional, previously aged Chinook from 2-3 stocks without the benefit of age data.
- Again, the goal is to produce ages similar to experienced readers most of the time. Differences are to be reviewed. If consistency with self and others is 60-70% proceed to stage 2.

Stage 2:

- Independently age an additional ~400-500 fish while conducting precision tests to work towards consistency in attaining minimum 80% agreement with self and others. Differences are to be reviewed and discussed with the trainer.
- Once 80% agreement is being met most of the time the student can begin to participate in a limited role in production ageing, as the first reader. These samples, initially, will all be second read by an experienced Chinook reader and if the student consistently meets/exceeds the 80% agreement threshold, regular precision tests of 20% of the sample will be done rather than re-ageing the whole sample. If any sample falls below an 80% agreement precision result, it will be second read by an experienced Chinook reader.
- Meeting the minimum 80% agreement consistently graduates the student to stage 3.

Stage 3:

- The student continues to participate in production ageing and must maintain a minimum of 80% agreement to continue development.
- Once this consistency is achieved they can participate fully in production ageing as the first reader and tester for stocks with scale patterns considered to be fairly straight forward to age.
- During this stage the student will also work towards and meet the expected production rate of 40-50 fish/hr.

Stage 4:

- This stage will extend over a number of seasons and years in order to gain the depth and breadth of expertise to fully participate in production ageing of coast wide B.C. stocks and fisheries as the 1st reader and tester.
- Samples will have more challenging scale patterns with moderate to severe resorption, have less defined annuli and/or prominent checks and originate from terminal or mixed fisheries that include both life histories (ocean- and stream-type).
- For each new stock or mixed fishery the student will be provided instruction and will be the 1st reader for 500-1,000 fish from current production samples.
- A trainer or other experienced reader will team up with the student to complete the samples. They may spot-check or sometimes 2nd read an entire sample if warranted by unsatisfactory precision results. Some coaching may be required.
- The student will review any age differences to gain insights into interpretive issues.
- As with stage 3, the student will be expected to meet both quality (minimum 80% agreement) and quantity (40-70 fish/hr on 5 scales/fish samples) targets consistently for these more complex samples.

Chinook Training: Student: X Trainer: Z											
	Species	Sample #	Project Description	# Fish	Original %	Ages initial	% Agreement	Precision (n)	Time (hrs)	Date completed	Comments
STAGE 1:	Chinook	20080282	Big Qualicum River Project	100	98%	M-K	Training with Z				ocean type stock
	Chinook	20060170	Nass R. Co-mgmt Program (Nisga'a)	100	100%	S-D	Training with Z				stream-type stock stock
	Chinook	20070295	Big Qualicum River Project	250	100%	J-D		2nd read		1209025	2nd read with access to ages
	Chinook	20090042	Nass R. Co-mgmt Program (Nisga'a)	250	97%	K-M		2nd read		1209027	2nd read with access to ages
	Chinook	20070284	Big Qualicum River Project - unmarked males	140	96%	J-D	83	140		1210002	independent reading
	Chinook	20120025	Lower Stikine Commercial Sampling	350	97%	J-D	79	350	7	1210910	independent reading
STAGE 2:											
	Chinook	20120072	Lower Stikine Commercial Sampling	200	90%	K-M	85	200	5	1210912	independent reading
Self Precision:	Chinook	20090042	Nass R. Co-mgmt Program (Nisga'a)	200	95%	X-X	92	1st 200 tested	5	1210913	
1st Prod. Sample	Chinook	20120073	Lower Stikine Commercial Sampling	275	94%	X-Z	82	55	6	1210916	
STAGE 3:	Chinook	20120037	Albion Chinook Test Fishery	250		X-Z	82%	50	5	1210925	April - June sample variety of ages 1& 0 FW. A few CWT's
	Chinook	20120039	Albion Chinook Test Fishery	360		X-Z	87%	72	9	1211010	July-Aug sample; mix of ages
	Chinook	20120004	Area 3,4 Creel Survey	60		X-Z	90	12	1.5	1211015	
Note: X went on to do 1st readings on 2012 Albion Chinook Test Fishery samples: 20120360-363 with precision results of 87-89%											
X ready for production ageing on more difficult samples ex. Harrison R. Chinook Enumeration 20120454-455, with Z as precision tested/ spot checked											
STAGE 4:											
More stocks, resorption on many; precision testing other readers' samples											
1301107	Chinook	20120454	Harrison River Chinook Enumeration	231		X-Z	89	46	13.00	1301111	
1301114	Chinook	20120455	Harrison River Chinook Enumeration	333		X-Z	93	67	11.00	1301118	
1301125	Chinook	20120261	Johnstone Strait Creel Survey	32		X-Z	80	10	1.50	1302306	
1301128	Chinook	20120258	Johnstone Strait Creel Survey	233		X-Z	88	47	6.00	1302307	
1302322	Chinook	20120431	Thompson Aggregate Chinook Bio-Sampling	101		M-X	95	20	3.50	1302322	
1312112	Chinook	20120274	W.C.V.I. Chinook Escapement	326		X-Z	94	65	9.25	1312316	
1401103	Chinook	20130404	Harrison River Chinook Enum. - Keystream	353		A-X	93	71	7.75	1401115	
1401109	Chinook	20130405	Harrison River Chinook Enum. - Keystream	384		A-X	84	77	8.00	1401116	

Figure 3. Training plan form for student learning to age Chinook scales.

4. Production ageing system

The SCL's production ageing system is complex, designed to manage workload and includes a series of checks and balances to produce best quality age data efficiently to

meet stock assessment deadlines. A sample tracking Excel file (Fig. 4) is kept to monitor sample progress and the roles of various staff are identified to ensure best quality age data through a series of QC steps and application of standards.

For the most part, two SCL readers are involved with processing a sample. Team members pair up to coordinate and complete samples keeping due dates in mind. They are designated as the first (primary) or second reader (tester). The first reader ages the whole sample while the tester ages a randomized independent subsample. Sometimes a third is called in to help out when agreement between the first two is elusive. Independent (blind) measurement of quality is carried out through precision tests and the use of available known-age techniques. Non-independent (access to first readings) data is generated during the resolution process after precision testing is concluded. This is a matter of expediency as continuing the independent processes beyond the tester would significantly increase the effort required to complete samples and negatively impact SCL capacity.

E SALMON

	Date Started	Species	Sample #	Project Description	# Fish	# Structures Scales	Otos	Fins	% Agreement Scales	Otos	Fins	Proc. n	Agers Initials	Time (hrs.) 1st Read	QC1	QC2	CWT % agree.	Date Complete	Comments
1	'14/01/03	Chinook	2013/0333	Lower Shuswap Chinook Keystream	163	1030			90			21	KC>JM	4.00	0.75	29	100	'14/01/21	CWT n = 11
2	'14/01/03	Chinook	2013/0404	Harrison River Chinook Enum. - Keystream	353	1765			93			71	AT>CC	7.75	1.75	77		'14/01/15	
3	'14/01/03	Chinook	2013/0436	WCVI SEF (Tranquil Creek)	54	540			100			10	JG>KC	2.50	0.50	15		'14/01/31	
4	'14/01/06	Chinook	2013/0414	Cowichan Adult Enumeration/Productivity Study	320	1600			91			62	JM>MH	4.50	1.00	71	88	'14/01/15	CWT n= 41
5	'14/01/06	Chinook	2013/0347	WCVI Chinook Escapement - Leiner River	102	510			95			21	CC>DG	3.00	0.50	26		'14/01/07	
6	'14/01/07	Chinook	2013/0348	WCVI Chinook Escapement - Gold River	71	490			100			14	CC>DG	2.00	0.50	16		'14/01/09	sample had both 10A and 5A format
7	'14/01/08	Chinook	2013/0407	Chilliwack River Chinook	103	515			90			20	MH>JM	1.75	0.25	22		'14/01/22	
8	'14/01/09	Chinook	2013/0329	Quinsam River Project	90	450			100			18	BC>JM	1.50	0.25	21		'14/01/13	
9	'14/01/07	Chinook	2013/0233	Chilko River Adult Chinook (M/R)	209	2090			76			42	DG>KC	9.25	4.00	76		'14/01/31	
10	'14/01/09	Chinook	2013/0394	Albion Chinook Test Fishery	290	1450			76			55	CC>AT	10.00	2.00	88		'14/01/13	
11	'14/01/09	Chinook	2013/0405	Harrison River Chinook Enum. - Keystream	384	1920			84			77	AT>CC	8.00	2.00	80		'14/01/16	
12	'14/01/08	Chinook	2013/0408	Chilliwack River Chinook	284	1420			91			56	MH>JM		1.00	64		'14/01/15	
13	'14/01/09	Chinook	2013/0332	Lower Shuswap Chinook Keystream	143	1430			93			29	JM>KC	4.00	0.75	32	94	'14/01/31	CWT n = 20
14	'14/09/09	Chinook	2013/0412	Chilliwack River Chinook	125	625			94				MH>JM	1.75	0.50	29		'14/01/22	
15	'14/01/13	Chinook	2013/0395	Albion Chinook Test Fishery	277	1385			95			55	CC>AT	10.00	1.75	73		'14/01/14	
16	'14/01/10	Chinook	2013/0335	Lower Shuswap Chinook Keystream	103	1030			81			21	JM>KC	2.50	0.50	26	94	'14/01/15	CWT n = 19
17	'14/01/13	Chinook	2013/0328	Lower Shuswap Chinook Keystream	54	540			100			11	JM>KC	1.25	0.25	11	100	'14/01/20	CWT n = 15
18	'14/01/14	Chinook	2013/0329	Lower Shuswap Chinook Keystream	120	1200			92			24	JM>KC	2.75	0.50	27	100	'14/01/20	CWT n = 33
19	'14/01/15	Chinook	2013/0331	Lower Shuswap Chinook Keystream	218	2180			84			44	KC>DG	5.50	1.25	67	100	'14/01/22	CWT n = 48
20	'14/01/15	Chinook	2013/0235	Chilko River Adult Chinook (M/R)	215	2150			88			43	DG>KC	8.00	2.00	51		'14/01/31	
21	'14/01/15	Chinook	2013/0411	Chilliwack River Chinook	266	1330			91			53	JM>MH	3.00	1.00	61		'14/01/16	
22	'14/01/15	Chinook	2013/0410	Chilliwack River Chinook	232	1160			97			46	JM>MH	2.75	0.75	50		'14/01/17	
23	'14/01/16	Chinook	2013/0406	Harrison River Chinook Enum. - Keystream	403	2015			91			81	CC>AT	10.00	1.50	95		'14/01/22	
24	'14/01/16	Chinook	2013/0334	Lower Shuswap Chinook Keystream	182	1820			97			36	JM>KC	3.75	0.50	38	91	'14/01/20	CWT n = 34
25	'14/01/20	Chinook	2013/0330	Lower Shuswap Chinook Keystream	162	1620			88			32	KC>JM	3.75	0.75	48	93	'14/01/24	CWT n = 32
26	'14/01/20	Chinook	2013/0343	Big Qualicum River Project	250	1250			88			50	BC>AT	3.25	1.50	66		'14/01/27	
27	'14/01/20	Chinook	2013/0354	W.C.V.I Chinook Escapement - Tlupana R.	31	155			90			31	CC>DG	0.50	0.00	12		'14/01/21	
28	'14/01/22	Chinook	2013/0336	Lower Shuswap Chinook Keystream	97	970			84			19	DG>JM	2.50	0.25	24	100	'14/01/22	CWT n = 15
29	'14/01/20	Chinook	2013/0344	Big Qualicum River Project	250	1250			82			50	BC>AT	3.50	1.75	64		'14/01/27	
30	'14/01/21	Chinook	2013/0409	Chilliwack River Chinook	247	1235			92			50	MH>JM	3.75	0.50	55		'14/01/22	
31	'14/01/22	Chinook	2013/0355	W.C.V.I Chinook Escapement - Gold River	179	895			78			36	CC>DG	5.50	0.75	53		'14/01/27	
32	'14/01/23	Chinook	2013/0476	Chilliwack River Recreational Fishery	53	265			100			10	MH>DG	1.00	0.25	12		'14/01/27	
33	'14/01/23	Chinook	2013/0356	W.C.V.I Chinook Escapement - Burman River	286	1430			93			57	CC>DG	8.00	0.75	66		'14/01/29	
34	'14/01/22	Chinook	2013/0337	Lower Shuswap Chinook Keystream	58	580			75			12	DG>JM	1.50	0.25	17	100	'14/01/24	CWT n=6
35	'14/01/22	Chinook	2013/0353	Conuma River Hatchery	230	1150			87			46	JG>JM	4.00	1.25	61		'14/01/29	
36	'14/01/27	Chinook	2013/0352	Conuma River Hatchery	206	1030			90			41	JG>JM	4.00	1.00	54		'14/01/29	
37	'14/01/30	Chinook	2013/0413	Cowichan River CID	123	615			83			24	MH>JM	1.50	0.50	28		'14/01/30	
38	'14/01/31	Chinook	2013/0383	Wannock (Owikeno) Co-Mgmt Program									KC>						
39																			
40																			
41	'14/01/03	Sockeye	2013/0311	Somass River Sockeye Escapement (GCL)	7	14			2nd read			0	JG>JM	0.00	0.00	7		'14/01/06	
42	'14/01/03	Sockeye	2013/0312	Somass River Sockeye Escapement (Sproat R)	34	68			100			10	JG>JM	0.25	0.00	10		'14/01/06	
43	'14/01/29	Kokanee	2013/0345	Alouette Lake Parental Analysis	168	336			97			36	DG>JM	3.00	0.75	50		'14/01/30	
44																			
45	'14/01/07	Coho	2013/0226	Skeena River Test Fishery	207	1035			2nd read			0	MW>JM		2.00	207		'14/01/13	
46	'14/01/10	Coho	2013/0227	Skeena River Test Fishery	169	845			91			34	MW>JM		2.75	62		'14/01/16	

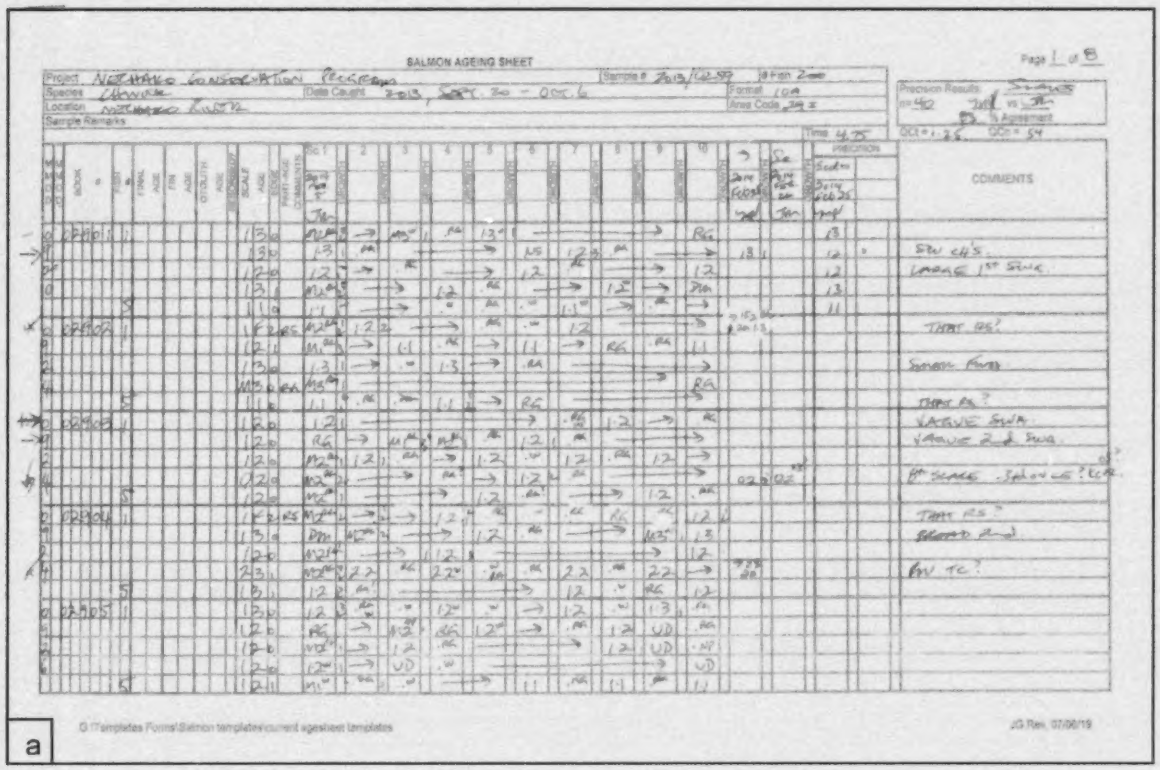
Apr13 | May13 | June13 | July13 | Aug13 | Sept13 | Oct13 | Nov13 | Dec13 | Jan14 | Feb14 | Mar14

Figure 4. Excel Sample Tracking sheet used to track progress of Chinook samples through the SCL production ageing system. It records the date the sample was started, ID information, fish numbers, precision results, time to age the sample and date completed.

a) Salmon age data sheet standards

Standard SCL hard-copy salmon age data (Fig. 5a) sheets have evolved over time. The sheets are geared towards readers' needs to express age and record issues surrounding the age determination and resolution process. The salmon age data sheets were developed to record the ages for each reader and each scale collected from a fish (1, 2, 5 or 10) (MacLellan 2004). Each reader involved with a sample is responsible for filling out sheets according to set protocols (Appendix 1).

Salmon age data sheets have a header section for sample metadata. The header section includes information such as species, date of capture, sample location, number of fish in sample, precision results, processing times for the first and second readers and numbers of specimens involved in the QC process as well as general comments. The body of the sheet has a row for each fish with headings: fish ID, final age (type), "working columns" for age estimates for each scale (headed by: method employed, date aged and reader ID), and finally reader comments. Readers make use of a number of codes to identify scale condition. Separate precision age data sheets (Fig. 5b) were developed for independent testing and require abbreviated header information. Appendix 1 describes in detail the protocols used to record data onto the salmon age data sheets.



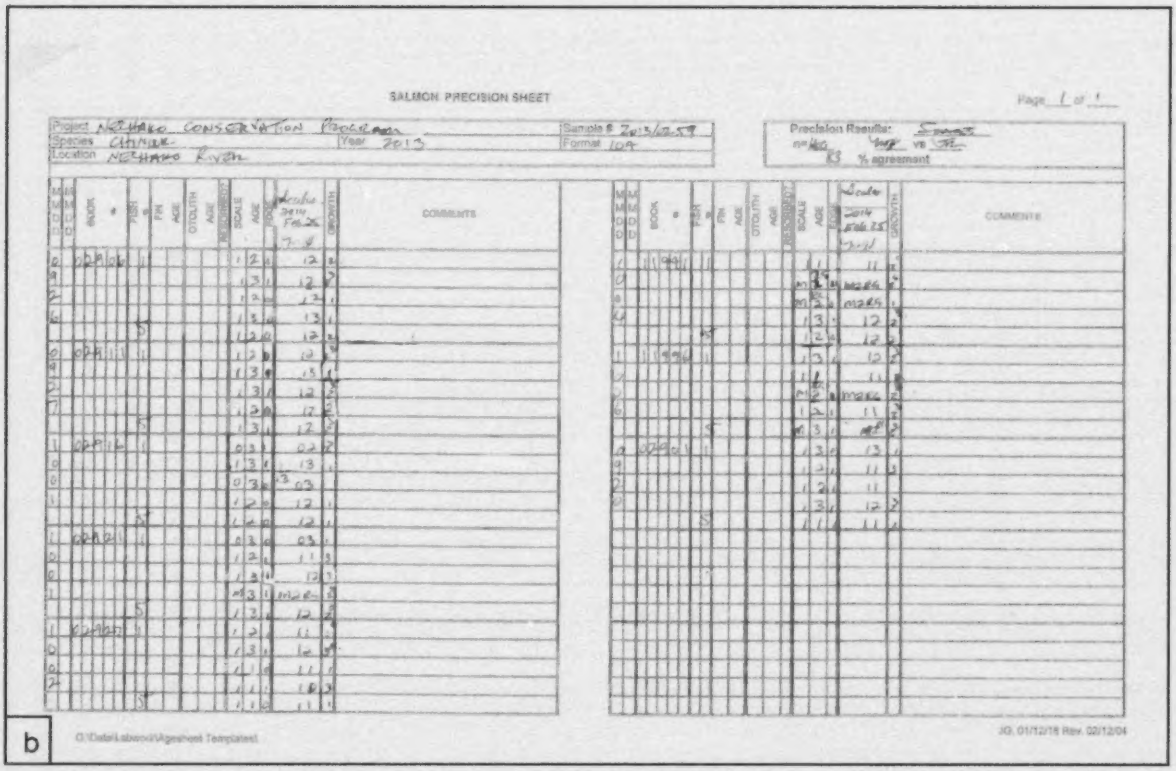


Figure 5. Salmon a) age data sheet (10 scales per fish example) and b) precision sheet. Each sheet has a header to record sample information with each row containing age data for a fish and for each scale. The columns include the sample date and fish ID as well as reader ID, ageing method used and date aged.

Expressing age uncertainty – No age and part ages

Age readers are often faced with a dilemma when unable to confidently assign one defined age to a fish. For example, "Is it 1.2 or 0.2?" Ambiguous scale patterns may make it difficult to apply criteria with certainty or perhaps the sample suffers from collection errors or poor preparation. There is pressure to deliver one age per fish that can easily be keypunched into databases. Reader biases arise from various circumstances such as: knowledge of dominant age types or preference to age older rather than younger. Hence, a production age system should have some options built into it to allow readers to express uncertainty. These kinds of expressions alert other readers to issues and the client to the quality limitations of the age data they use.

SCL readers, however, are generally encouraged to make a decision on a single age for each Chinook whenever possible. QC procedures are in place to provide additional checks by other readers to encourage resolution. The SCL expresses uncertainty in the "working columns" of the age data sheet by recording multiple age-type possibilities per scale. When readers cannot resolve either the freshwater (FW) or saltwater (SW) age for a fish, a part-age (e.g. 1F or M2) is recorded in the final scale age column of the age data sheet. If both the FW and SW age can't be resolved, no age (NA) is recorded. It

is not uncommon for significant numbers of part-age fish to result from Chinook escapement samples due to regenerate and/or resorbed scales. FW age is not assessed if a regenerate scale is missing one or more circuli in the centre (focus) and/or if the first circulus is large and irregularly shaped. SW age is not assigned if the number of saltwater annuli (SWA) can't be estimated with certainty on resorbed scales.

b) Salmon age designation system

Designating age for salmonids is complex because of their anadromous life histories. Clients want to know the number of years spent in fresh and saltwater to help understand life histories and delineate stocks to make management decisions. SCL readers can work with both the European (E) and Gilbert-Rich (GR) age designation systems (Koo 1962). But, E is the standard recorded on SCL age data sheets. The E age is input to the Pacific Age Database System (PADS) where it is converted to GR. The age data report sent to clients lists ages in both designations (Table 2). The SCL uses the E system because it expresses age or age class while the GR system denotes "year of life". GR has historically been used by DFO Pacific region managers for assessments and is the reason why the SCL provides ages in both designations. Managers favour the GR system for ease of calculating brood year.

The E system consists of two numbers separated by a decimal. The first number represents the number of years or winters the salmon spent in freshwater and the second number time spent in the ocean. The two numbers added together provide total age or age class, e.g. 1.3 = 1 year over-wintered in freshwater and 3 in the ocean. The total age is 4 years old. The GR system also consists of 2 numbers of which the second is a subscript. A 1.3 E age translates to a 5_2 GR age and is spoken as "five sub two". The GR expression indicates that the fish was caught in its 5^{th} year of life and went to sea during its 2^{nd} year of life. Brood year would be calculated by subtracting 5 from the calendar year caught. The fish would be referred to as a "five year fish" by managers. By SCL standards this fish is 4 years old and would not be 5 until it reached the next January 1^{st} birth date. The SCL works with and communicates using the E method as it designates age class and is less confusing than the GR method.

Table 2. European and Gilbert-Rich salmon age designation systems.

Conversion table for salmon age data: European to Gilbert-Rich Designation								
European system				Gilbert-Rich system				
Age designation	No. FW annuli	No. SW annuli	Total age	Age designation	Yr of life caught	Yr of life went to sea	Yr caught	Brood yr
0.0	0	0	0	1_1	1	1	2002	2001
0.1	0	1	1	2_1	2	1	2002	2000
0.2	0	2	2	3_1	3	1	2002	1999
0.3	0	3	3	4_1	4	1	2002	1998
0.4	0	4	4	5_1	5	1	2002	1997
0.5	0	5	5	6_1	6	1	2002	1996
0.6	0	6	6	7_1	7	1	2002	1995
1.0	1	0	1	2_2	2	2	2002	2000
1.1	1	1	2	3_2	3	2	2002	1999
1.2	1	2	3	4_2	4	2	2002	1998
1.3	1	3	4	5_2	5	2	2002	1997
1.4	1	4	5	6_2	6	2	2002	1996
1.5	1	5	6	7_2	7	2	2002	1995
1.6	1	6	7	8_2	8	2	2002	1994
2.0	2	0	2	3_3	3	3	2002	1999
2.1	2	1	3	4_3	4	3	2002	1998
2.2	2	2	4	5_3	5	3	2002	1997
2.3	2	3	5	6_3	6	3	2002	1996
2.4	2	4	6	7_3	7	3	2002	1995
3.0	3	0	3	4_4	4	4	2002	1998
3.1	3	1	4	5_4	5	4	2002	1997
3.2	3	2	5	6_4	6	4	2002	1996
3.3	3	3	6	7_4	7	4	2002	1995
3.4	3	4	7	8_4	8	4	2002	1994
4.0	4	0	4	5_5	5	5	2002	1997
4.1	4	1	5	6_5	6	5	2002	1996
4.2	4	2	6	7_5	7	5	2002	1995
4.3	4	3	7	8_5	8	5	2002	1994

c) Productivity standards

Good quality data is the first, but not the only issue of concern for production ageing. High volumes must also be produced and in some cases, especially for salmon, the SCL works with turnaround times as short as 24 hours. Productivity is important.

The SCL keeps records of the time it takes readers to age samples once through (first read) to the nearest quarter hour. This data has been analyzed to build production reader target rates (number fish aged/hour). Average rate and rate range targets were calculated (Table 3) for salmon species processed from 1999 to 2004. At least 6-8 experienced readers were involved having aged thousands of fish. The targets reveal that Chinook are the most challenging salmon species to age having the lowest average rate of 60 fish/hr.

Table 3. Reading rate (productivity) targets for salmon species aged by the SCL.

Species	Ageing Method	Sample size (99/00-04/05)	Average reading avg. rate targets (#/hour)	Reading rate ranges (#/hour)
Chinook	scales	186682	60	40-80
Chum	scales	86816	98	60-125
Coho	scales	82096	81	60-120
Sockeye	scales	176834	80	50-90

An experienced Chinook reader is expected to meet established speed targets most of the time. The target rate ranges are delineated by 25% and 75% quartiles. Ranges were produced because not all samples and readers are the same. Rate can be affected by: species, stock, sample quality, complexity of life history, scale pattern clarity, number of scales per fish, severity of scale resorption and/or age composition and reader expertise. Generally, experienced SCL Chinook scale readers spend about 1 minute determining the age of a single fish.

d) Data quality standards

i) Precision

Precision testing is a key QC tool used by the SCL to assess quality. All Chinook scale samples are tested. Test results are viewed as an opportunity to learn and advance expertise (ensure similar application of criteria) while monitoring and improving the quality of age data that goes out to clients. Recognizing the importance of quality data, SCL readers feel a level of assurance knowing that their work is checked to ensure that best quality age data will be passed on to clients. It`s a team effort. The minimum precision target set for most Chinook stocks is 80% agreement, with results of 90% or better often attained.

The SCL currently assesses precision via percent agreement. More advisable stringent statistical tests such as Average Percent Error and Co-efficient of Variation (Beamish and Fournier 1981, Chang 1982, Kimura and Lyons 1991, Campana et al. 1995) are not used by the program yet because only the final age is input to the salmon age database. All precision tests are conducted independently (blind). The tester does not have access to the first reader's ages. The 80% agreement precision target for Chinook is based on analysis of many different reader's results for thousands of fish and multiple stocks over two decades of samples.

Twenty percent of each salmon sample is independently aged. The first reader has no knowledge of which fish will be tested while ageing. Rather than choosing individual fish, whole scale books are identified for testing by rolling dice after the first reading is completed. Thereafter, every 5th book is tested to evenly distribute monitoring throughout the sample. All fish in a book are tested unless the last book chosen contains more fish than are required for the test.

Books to be tested are identified by the first reader with a "dash" beside the book number on the original age data sheet. They prepare a separate precision test sheet (sample header information and scale book ID numbers) for the tester. The tester retrieves the sample and test sheet and independently re-ages the subsample. Upon completion, the tester will recover the primary reader's ageing sheets, transfer the test ages to them and calculate percent agreement. The tester then begins the process to resolve any differences or biases showing up from the precision test and also will 2nd read any fish that have been flagged by the 1st reader in the sample. If the 80% precision target is not met then a portion or all of a sample is re-aged. If biases can be identified, only those affected ages, aside from the precision test, will be re-aged by the tester. If there appear to be no biases, a problematic situation arises whereupon, a "random" number of fish or perhaps all will be re-aged to determine if more differences are identified. Once the sample has been reviewed by the precision tester, the sample will be given back to the first reader to go over any unresolved fish until both readers agree on the final age assignments.

ii) Accuracy

The SCL uses Coded Wire Tag (CWT) information whenever available to independently validate the accuracy of scale ages for hatchery Chinook. Release information provides total and FW age confirmation. The reader is not allowed access to CWT information when originally ageing a sample. CWT ages are checked after production ageing is completed. If there is a discrepancy between assessed and CWT age the SCL reader does not automatically change the age on the data sheet to agree with the CWT age. A change must make sense given the scale pattern when reviewed again with CWT information. The change is only made if the reader expressed uncertainties on the age data sheet and/or recorded an alternative age that matches the CWT age.

The SCL also uses genetic information to help improve the accuracy of ageing some Chinook stocks when available. DNA analysis, done by various salmon programs,

identifies the probability that fish belong to certain stocks within a mixed fishery. If these stocks are known to be predominantly stream or ocean-type, this assists in the verification of the FW age of scales. As per CWTs, DNA information is checked after the fact and ages are only changed if it makes sense considering the scale pattern.

5. Scale age determination method – criteria, standards & procedures

a) Terminology standards

The main tasks of a salmon scale reader are to consistently and accurately count annual growth zones and identify in which environment they were formed. This often means interacting with other readers. Therefore, clear communication becomes important to ensure that readers are talking about the same thing and applying criteria in a similar way. The SCL employs standard terminology (Chilton and Beamish 1982, MacLellan 1997) to ensure consistent exchange of information. The Glossary at the end of this document provides definitions of terms used in this document.

b) Standards to generate age data

During production ageing of Chinook scales, SCL readers estimate age based on growth pattern characteristics, not biological factors such as specimen length, weight, maturity and/or sex of individual fish. It should be noted, however, that these factors may have had a role during the development phase for the scale method when they would be converted into pattern recognition criteria such as location, shape and size of annual growth zones. Biological data are not available to SCL readers during age determination as it is considered to be biasing. These data may be taken into consideration, but not until after the fact, and is strictly left up to data users to employ. The expectation is that clients will provide feedback to the SCL if they find that age data is in conflict with biological data. Criteria may be modified, based on this kind of feedback, especially if it would make a difference for a significant proportion of a species or stock.

To generate accurate salmon age data the SCL reader must have access to 3 pieces of sample data: species, catch location and date caught. A standard birthdate of January 1st is factored in. Although usually discernable once the scales are examined, species ID provides general growth pattern expectations. Likewise, location, especially for escapement samples, helps when stock-specific pattern criteria needs to be applied. Finally, the date caught is critical when assessing age class.

i) Date of capture information

The SCL will not age a sample unless the date of capture is provided. To assess age accurately, the date of capture is necessary and must be available to the reader. The year is not important, but the month is essential. The day is also very useful in terms of placement within a month; early, mid or late. This can be critical to the age decision-making process, especially in spring and fall when scale growth zone deposition is changing from fast or slow growth conditions. The month and day provide expectations for the type, size and completion of the last growth zone (summer/winter) on the scale margin. The date requirement ensures that the last annual growth zone visible on the scale edge, complete or not, is assigned to the correct calendar year of formation, either the previous or catch year. Without accurate catch date information a fish can be miss-aged by one year.

ii) January 1st birthdate standard

Age or age type is determined for salmon using a January 1st birthdate (INPFC 1957) with reference to the catch date or the date the fish died. Employment of a January 1st rather than a biological birthdate ensures that all fish born in the same calendar year are grouped together for analysis. Figure 6 illustrates how the SCL assesses age as scale growth progresses throughout the calendar year. A salmon is not designated a year older until January 1st. Use of different birthdates can lead to a discrepancy of one year during certain catch-times of the year causing difficulties when exchanging data with other agencies/groups that share data. The SCL, does however, make an "adjustment" for deadpitch samples (scales collected from dead fish) after January 1st. These samples are considered to have died in the previous calendar year ahead of scale collection. In this case, date of death is noted for determining age.

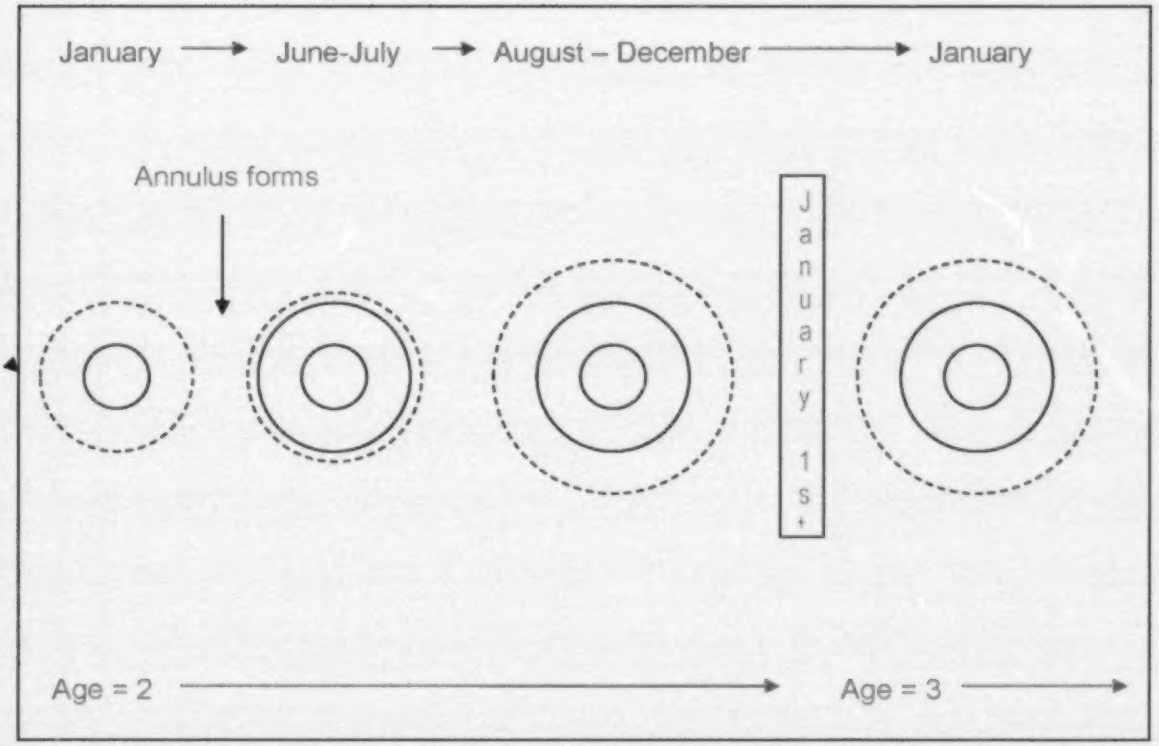


Figure 6. Illustration demonstrating how the Jan 1st birthdate is applied to salmon scales. The annulus (solid line) cannot be identified until new summer growth (wide white zone) begins to form. The annulus (last circulus of winter zone) appears sometime in the late winter – early spring. This is followed by new year's growth that forms from June through to the end of winter past the January 1st date. The marginal growth zone (dashed line) that gradually becomes larger and fuller in the fall is not counted as another year until after Jan. 1st.

iii) Location information

Chinook stocks from B.C. and the Yukon experience myriad complex life histories, described as stream- or ocean-type, producing a range of age types. Stream-types spend one or more winters in freshwater while ocean-type fish go to sea during their first year of life. Fish that spend 2 winters in freshwater are quite rare in Canadian stocks. Generally, those stocks found in southern B.C. tend to be ocean-type and those from northern B.C. and the Yukon are stream-type. Ocean-type stocks tend to give way to stream-type Chinook around B.C.'s Central Coast where a number of systems may support both types. There are exceptions to the north-south trend. For example, Fraser River Chinook stocks that spawn in its upper reaches are stream-type while those closer to tend to be ocean-type. However, there are a number of systems coast-wide that have both life history types. The SCL also ages mixed fishery samples that include stocks from Washington, Oregon and California, documenting all age types, life histories, and any unique scale patterns associated with them. Appendix 1 contains representative scale patterns of the age types found in major river systems by Region within BC and the Yukon.

Knowing sample location is generally very helpful, but more so when escapement samples are aged. Based on sample location, specific ageing criteria are utilized to determine both resorption, and stream or ocean-type scale patterns. Mixed- stock fishery samples present their own challenges obliging the SCL to fall back to most basic growth pattern criteria. This document does not cover criteria unique to specific B.C. and Yukon stocks but rather focuses on the basic criteria used to age any Chinook scale.

c) Basic scale ageing criteria

The basic criteria for ageing Chinook scales are similar to that of all salmon species. Age is determined by interpreting circuli growth patterns in terms of numbers of freshwater (FWA) and saltwater annuli (SWA) present. Circuli are growth ridges that form concentrically on the anterior portion of the scale exterior. The area that is bound by the first circulus is called the focus. Several circuli subsequent to the focus will form fully in all quadrants of the Chinook scale, in both the anterior and posterior.

The first circuli that form in the spring, whether in freshwater (FW) or saltwater (SW), are thicker and wider-spaced than those that form later in the fall and winter. FW circuli usually appear more delicate (thinner) and closer-spaced than SW circuli which are more robust in appearance and wider-spaced. FW annual zones are significantly smaller than SW zones. An SCL reader will always look at the overall growth pattern to get a first impression of age type before focusing in on individual annual zones. Marine annual zones on Chinook scales generally become proportionately smaller with each year. The first is usually the largest or at least as large as the second marine zone depending on stock and sometimes whether the fish has a stream- or ocean-type life history.

The reader must learn to discriminate three scale growth zones (Fig. 7):

1. Winter zone and associated annulus
   - forms during the fall, winter and early spring months
   - represents slower growth
   - consists of progressively closer-spaced and thinner circuli with the last close-spaced circulus of the zone defined as the annulus
   - annuli by definition form only once a year
2. Summer zone
   - forms during the late spring, summer and early fall months
   - represents a time of faster growth
   - consists of thick wide-spaced circuli
3. Check
   - forms within the normally fast-growing summer zone
   - represents a slowing of growth due to some kind of stress
   - usually consists of only a few tightly spaced and/or thinner circuli

One annual zone consists of a summer zone followed by a winter zone with annulus.

Essentially the reader's job boils down to the ability to differentiate annuli from checks and vice versa. If checks are counted over-ageing occurs. Checks (Fig. 7) can look very similar to annuli. They may exhibit some or many of the characteristics attributed to annuli but usually are less prominent. They can form both in the FW or SW zones of Chinook scales. The SCL does not count an annual zone until the annulus can be identified. This means that at least one thicker wider-spaced summer zone circulus must be visible beyond the annulus on the scale margin.

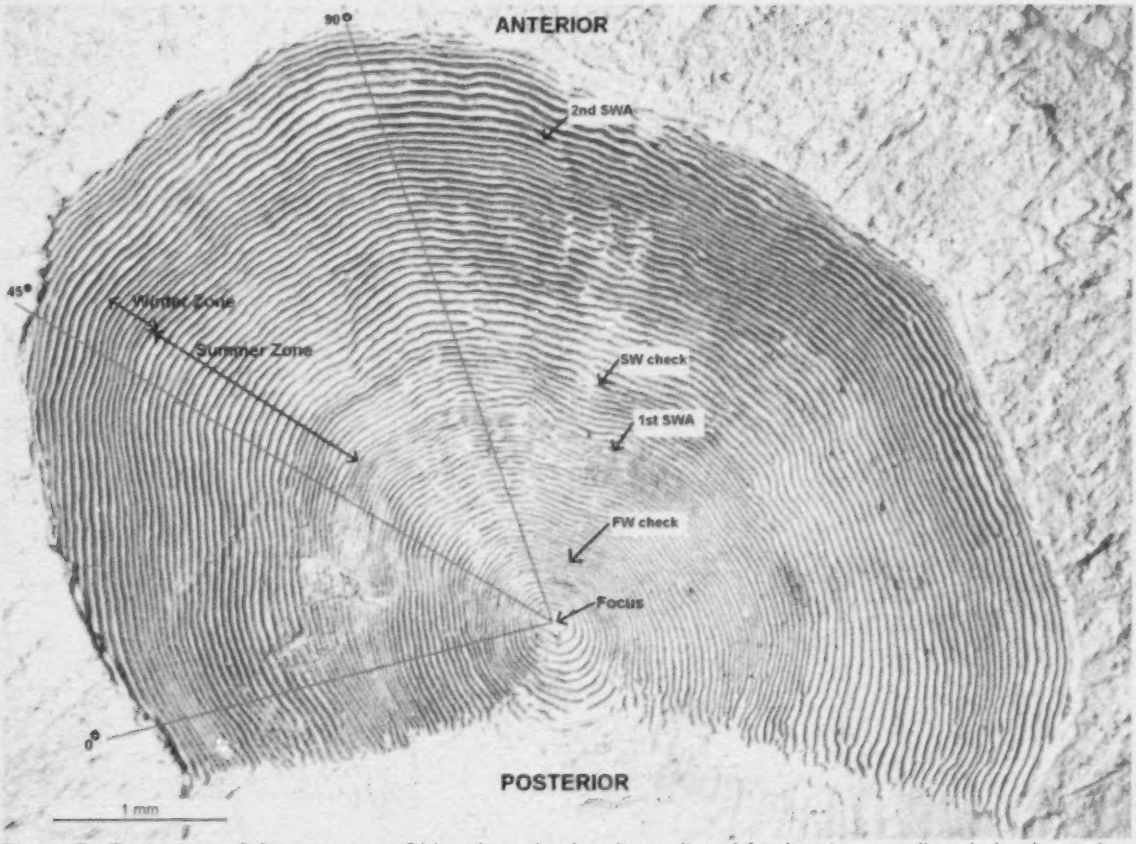


Figure 7. Typical age 0.2 ocean-type Chinook scale showing salt and freshwater annuli and checks and the summer and winter zones of the 2nd annual zone. The focus, posterior and anterior quadrants as well as standard axes (90° and 45°) used for measurements are labelled.

Determination of life history type and number of annuli are the basic tasks when estimating the age of a Chinook scale. Figure 8 demonstrates typical rather straight forward scale growth patterns for ocean- (0 FWA) and stream-type (1FWA) scales.

General criteria used to identify both FW and SW annuli on salmon scales:

1. Annulus is preceded by a band of successively closer-spaced and thinner circuli.
2. Circuli "cross-over", are broken and/or merge around the outer circumference of the winter zone.
3. Circuli "pinch" and bend in towards the focus along the posterior axis of the scale.

4. Annulus is followed by relatively wider-spaced and thicker circuli.
5. Circuli following annuli tend to turn outwards, away from the focus, along the posterior scale line.

Additional criteria used to identify FWA, in descending order of reliability and often dependent on Chinook stock:

1. Presence of FW spring plus growth beyond a FWA. Spring growth consists of a band of a few to several slightly thicker wider-spaced and relatively parallel FW circuli that surround the FWA. There is no pinching or bending-in towards the focus at its outer limits along the posterior scale axis. This zone represents a short period of time spent in FW in the spring after the annulus has been deposited before the smolt migrates to sea.
2. Presence of many FW circuli that appear densely packed together and are concentric around the entire focus area, known as a "cut out" (Yole 1989).
3. FWA is followed by significantly thicker and wider-spaced marine circuli. This represents a clear and distinct change from FW to SW.
4. A FW annual zone usually consists of at least 8-10 circuli.
5. Distance from the focus to the 1st SWA is larger than the distance from the 1st SWA to the 2nd SWA.
6. Circuli spacing in the 1st marine summer zone is very similar to the circuli spacing in the 2nd marine summer zone.
7. Presence of a prominent striation that extends into the posterior part of the scale, mirroring the location of the FW annulus.

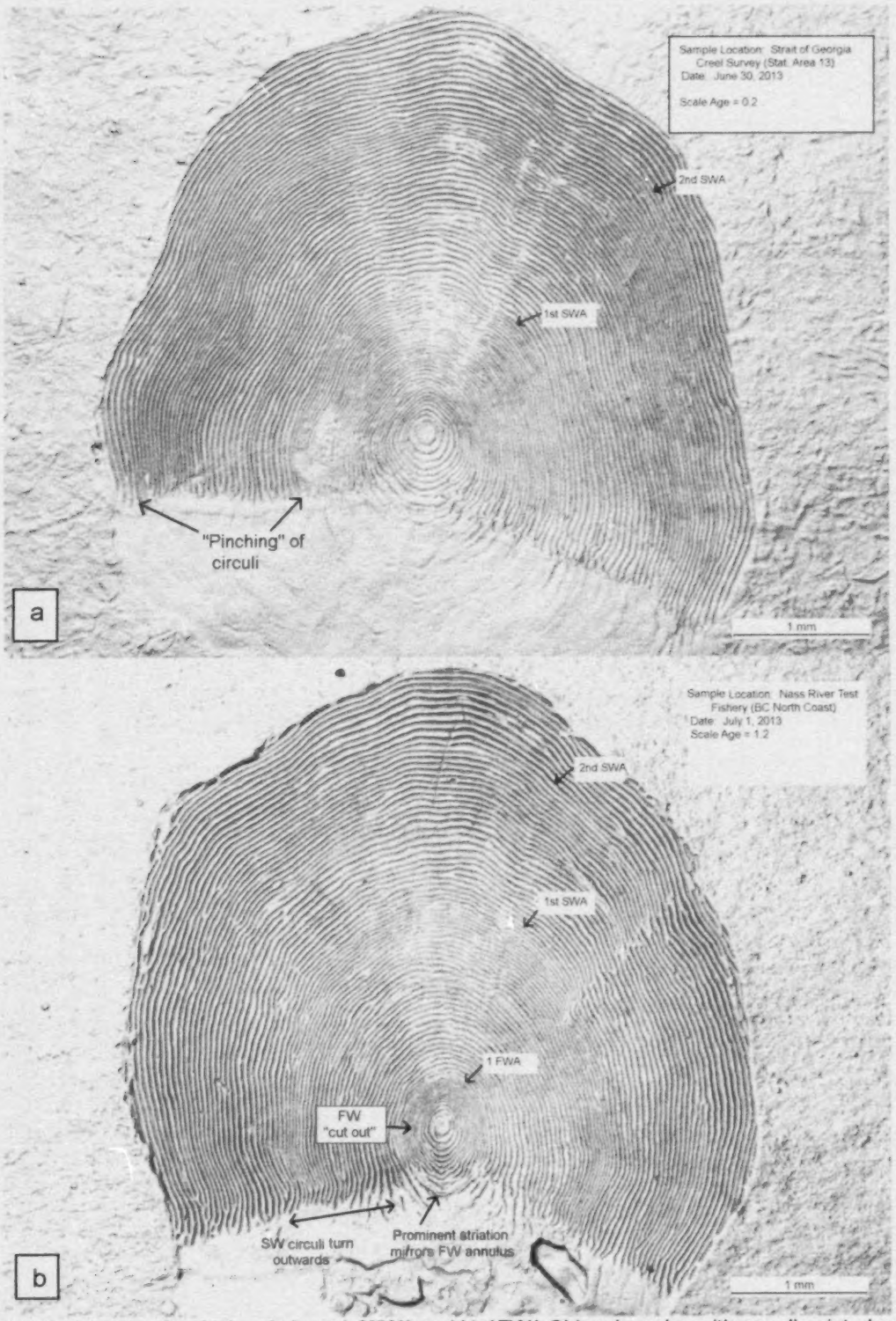


Figure 8. Images of typical and clear a) 0FWA and b) 1FWA Chinook scales with annuli pointed out.

d) Challenges for Chinook scale age determination

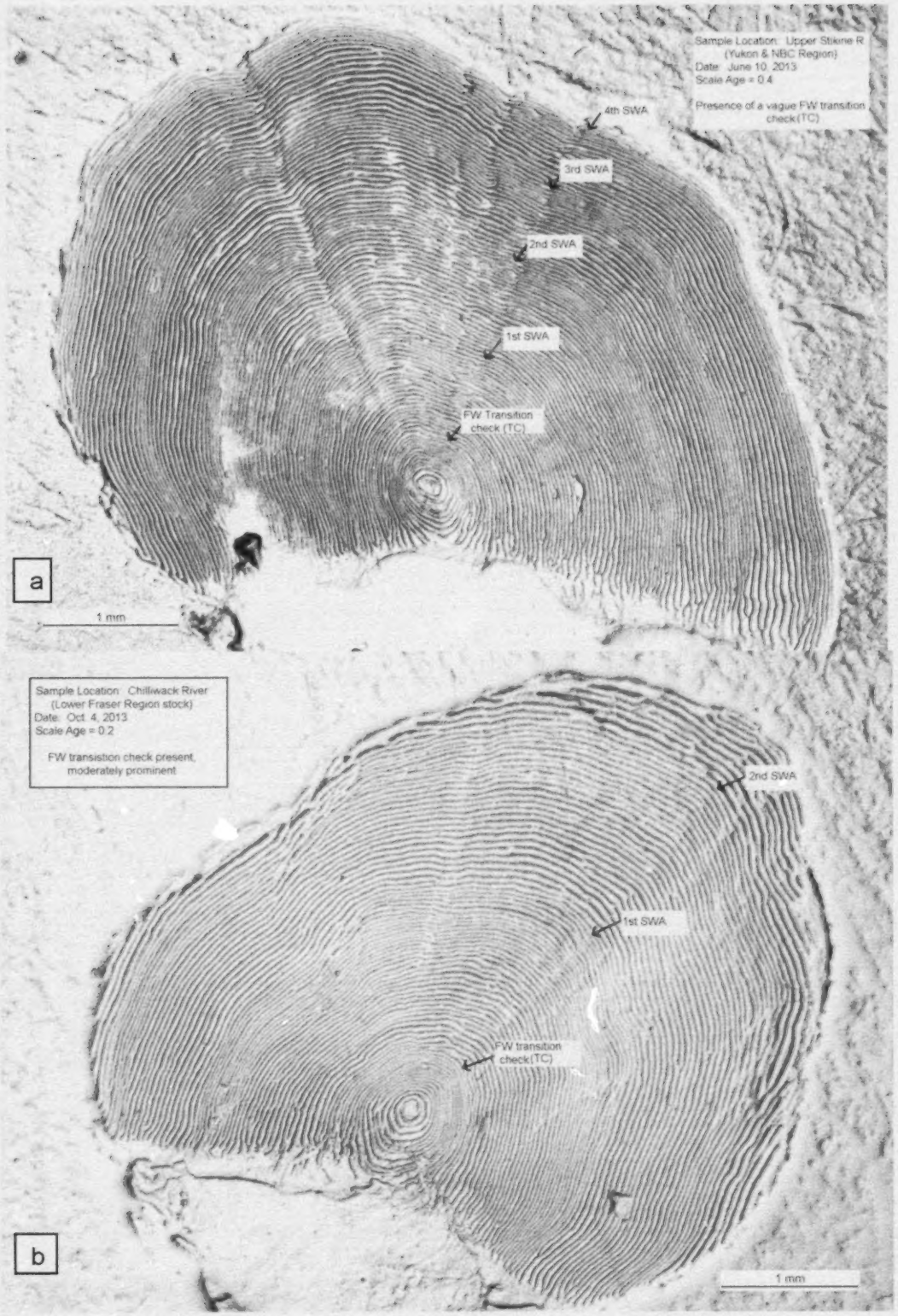
The main challenges to accurately ageing Chinook scales are:

1. Presence of prominent FW checks
2. Presence of prominent SW checks
3. Indistinct SWA
4. Determining if resorption is affecting age
5. Disproportionate SW annual growth zones
6. Unfamiliar US stocks in mixed fisheries

i) Freshwater checks

The biggest challenge the SCL faces when ageing Chinook scales is determining the presence or absence of a FWA as opposed to checks. Ambiguity results when both the general and the additional FWA criteria are not consistently reliable. In particular, the SCL finds that not all "additional" FWA criteria pertain to all Chinook stocks and/or fish in the same sample. These kinds of samples usually come from mixed fisheries, large river systems with a number of minor stocks or contain both hatchery and wild fish.

A prominent freshwater transition check (TC) may form at the end of FW growth in the first year (Fig. 9). The check is attributed to smolting stresses that slow growth. Sometimes the TC satisfies one or more criteria for an annulus and can appear as prominent. Knowing the stock origin can have a strong influence on whether to discount a check even when it is prominent. The SCL has learned that when faced with conflicting evidence for the presence of a FWA, it is more likely to be a check. This is based on information from CWT hatchery Chinook that are known-aged. The SCL also finds that scales from hatchery-reared Chinook are more likely to have a prominent TC's.


Sample Location: Upper Stikine R
(Yukon & NBC Region)
Date: June 10, 2013
Scale Age = 0.4
Presence of a vague FW transition
check (TC)
4th SWA
3rd SWA
2nd SWA
1st SWA
FW Transition
check (TC)
a
1 mm
Sample Location: Chilliwack River
(Lower Fraser Region stock)
Date: Oct. 4, 2013
Scale Age = 0.2
FW transition check present,
moderately prominent
2nd SWA
1st SWA
FW transition
check (TC)
b
1 mm

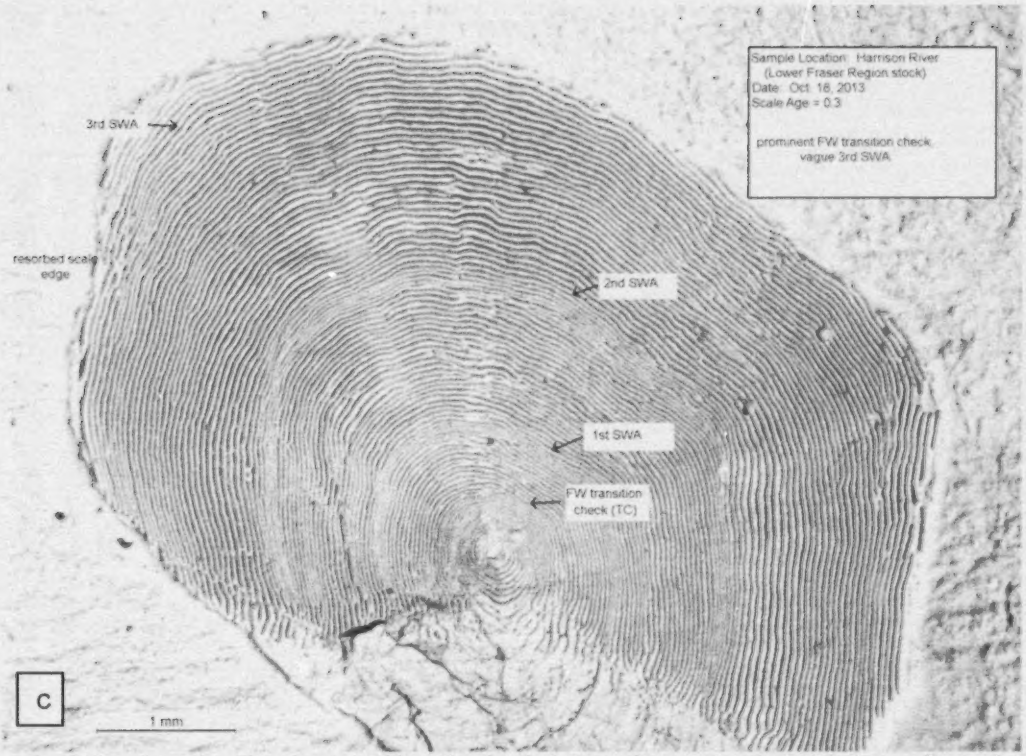


Figure 9. Chinook scales showing transition checks that range in prominence, a) not very, b) moderate, c) very.

ii) Saltwater checks

Checks in marine summer zones are generally easy to identify because only a few circuli are involved (~2-3). A saltwater check is preceded and followed by wide spaced circuli. The check can be difficult to identify if it seems to be located where an annulus is expected to be. The general expectation is that marine annual zones on Chinook scales start off with the first or the first and second being the largest followed by consecutively smaller years. A check will disrupt this pattern (Fig. 10) and cause later marine zones to appear unexpectedly small or large.

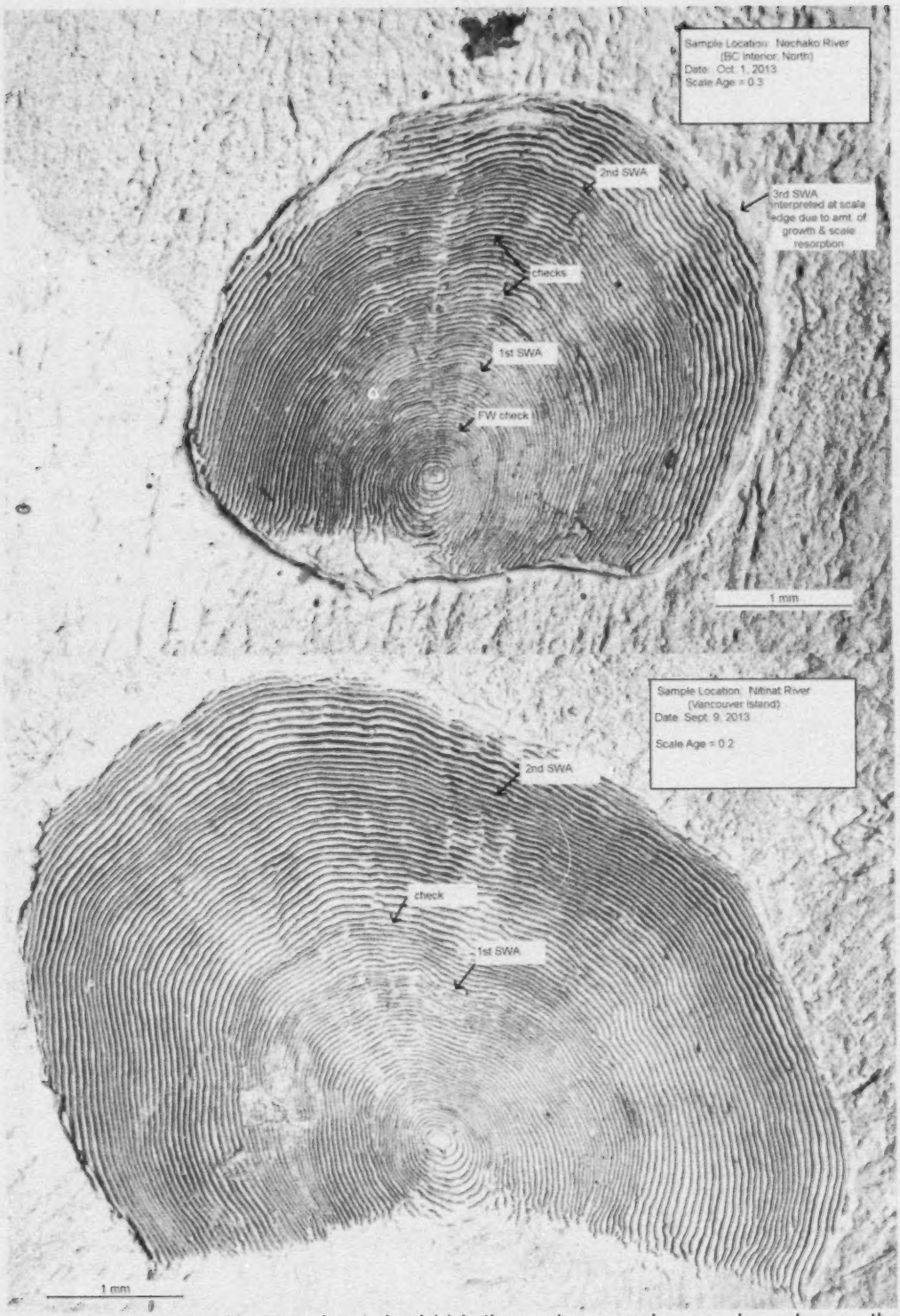


Figure 10. Chinook scales with a prominent check(s) in the marine annual zones. In each case, the spacing of SW annual zones would be atypical if the checks were counted.

iii) Indistinct saltwater annuli

Vague SWA are a challenge that can cause under-ageing of Chinook scales. The SCL attributes this kind of pattern to fish that do not experience much slowing of growth during the winter months. These annuli usually are not preceded by a typical winter zone with obvious narrowing and closely packed circuli. There is often little evidence of merging and pinching of circuli. The SCL reader will look for a vague SWA if there appears to be an annulus missing from an expected location that makes an annual zone appear larger than usual. A good area to look for indistinct annuli is along an angle from the vertical scale axis and for subtly and slightly more close-spaced circuli (Fig. 11). The first circulus of the next summer zone may be only slightly thicker and wider-spaced than the vague annulus.

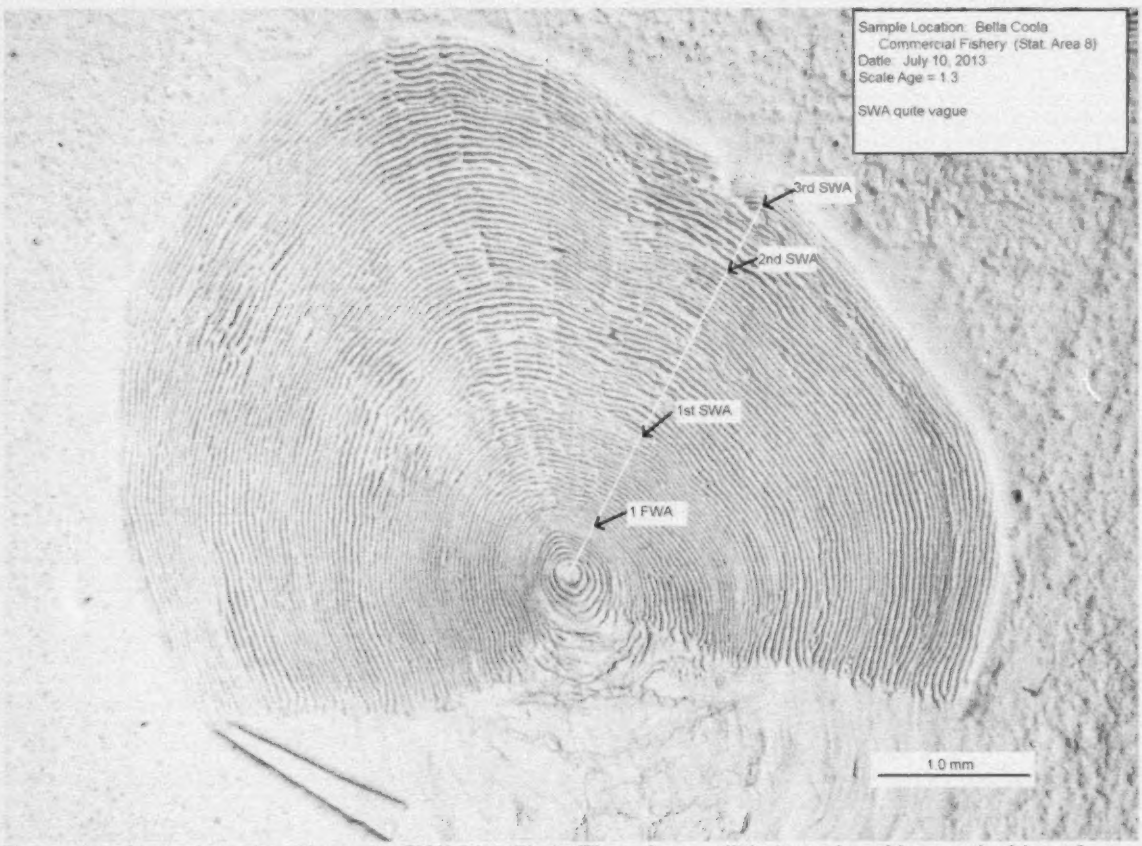


Figure 11. Chinook scale with vague SWA identified. There is very little to no breaking or pinching of circuli at the end of the winter zones. Look for subtle changes in circuli spacing and width to identify annuli.

iv) Scale resorption

The fourth biggest challenge to accurate ageing of Chinook scales is when resorption is a factor. Resorption occurs on the scales of mature fish. It may begin while the fish is still in the ocean, but is usually associated with returning to freshwater. Resorption takes place on the scale margin and in extreme cases on the inner surface of a scale. Resorbed scales have various amounts of missing growth on the margin that the SCL reader must assess in order to produce an accurate age.

The SCL is asked to age a large number of escapement samples with resorbed scales. To provide the most accurate ages the SCL developed some objective criteria to estimate whether or not an annulus is missing and if a year should be added to the marine age. Resorbed scale criteria is most often applied to samples from relatively long river systems, e.g. the upper Fraser River, or to central and northern B.C. and the Yukon stocks. It is known from CWT samples that southern B.C. stocks, including west coast Vancouver Island, rarely resorb back past the last formed marine annulus. Resorbed criteria are not often applied when ageing these stocks.

Resorbed scale criteria:

Resorbed criterion compares the size (width) of the last visible growth zone on the scale margin to the previous annual zone. Measurement is made to the visible margin of the scale which may or may not show circuli. Sometimes circuli are eroded away leaving behind only the clear scale plate. A growth code (see below) is assigned to describe relative size of the margin growth for each scale. Growth is measured (Fig. 12) by eye and using a pen to assess relative size of the last 2 annual zones visible on the scale. Measurement occurs wherever the maximum amount of growth is present on the scale as the rate of resorption is neither consistent between scales nor around the circumference of the scale (Fig. 13). Each scale collected from a fish is coded. The final age decision is made using the scale with the most growth beyond the last visible annulus.

<u>Codes describing relative size of last annual zone on scale margin:</u>

- 1= less than ¼ previous year (1-2 circuli)
- 1^2 = about ¼ previous year
- 2^1 = just short of ½ of previous year
- 2 = about half the width of previous year
- 2^3 = a little more than ½ of previous year
- 3^2 = just short of previous year
- 3 = same as previous year
- 3^+ = more than previous year

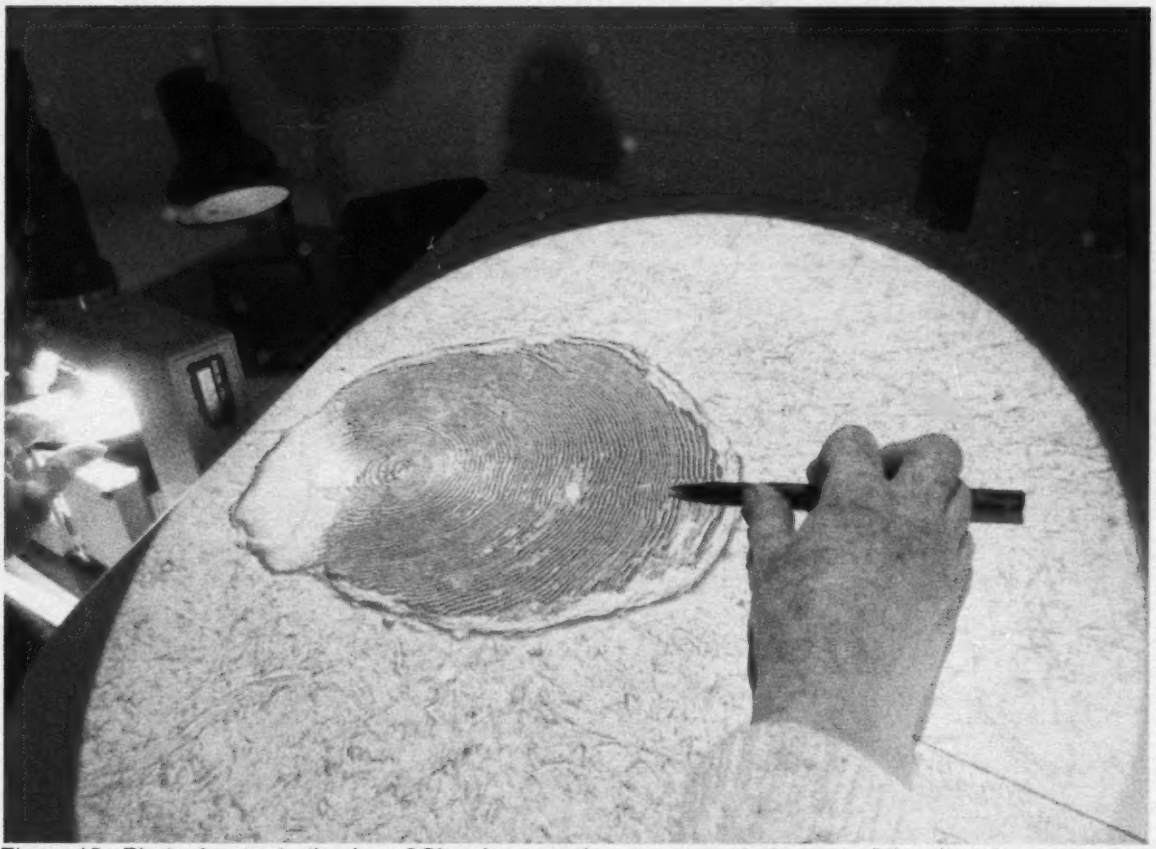


Figure 12. Photo demonstrating how SCL salmon readers use a pen to "measure" the size of annual growth zones on the scale image. The pen tip is placed on the last visible annulus and the thumb marks the furthest extent of the scale plate. The reader then moves the pen to the previous annual zone to compare width.

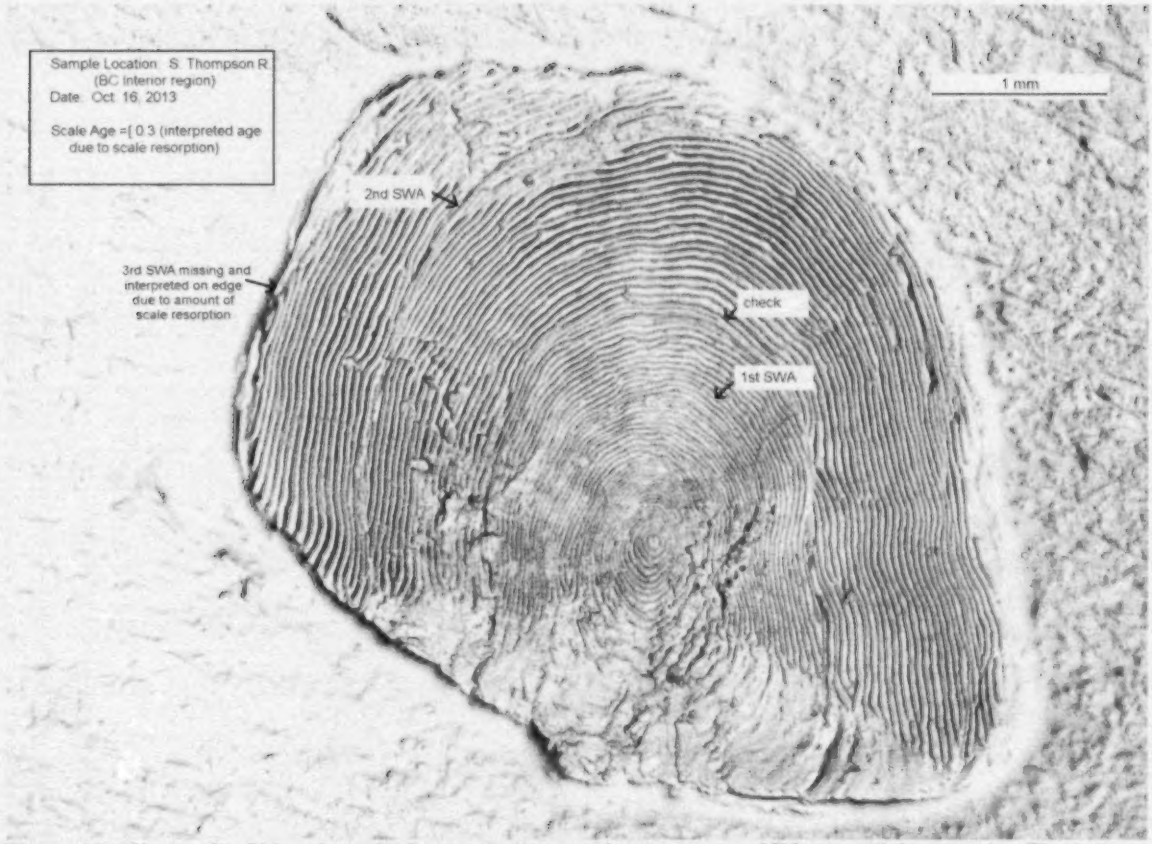


Figure 13. Photo of a Chinook scale demonstrating varying amounts of RS around the margin. The left hand side of the scale still has nearly a year's growth remaining and visible while the same zone has been mostly eroded away on the right hand side.

The SCL applies the above criteria to make determinations as to whether no, one or some unknown number of annual zone(s) is missing. A total age is assessed in the first two cases, but for the third only a FW age will be supplied. A year is added to the visible SW scale age in the case where one annual zone is determined to be missing and none to the case where no annual zone is missing. On the age data sheet this is identified as a resorbed age (RS) and the final age on the age data sheet will also be given an edge code (see below) to indicate how the reader assessed resorption. See Appendix 2 for more detail.

Edge codes for scales:

- blank = no resorption
- 0 = resorption present, but not affecting age
- 1 = resorption has eroded past the last annulus and it is assessed that one year should be added to the "visible" age of the scale
- 2 = the scale is resorbed to an extent such that it cannot be determined how many annuli are missing from the scale margin

- 3 = one year added to visible age due to date fish was caught (e.g. January – June)
- 4 = one year added to visible age due to date fish was caught and the scale is slightly resorbed, but not affecting age

The SCL has documented that different aged Chinook and stocks experience different rates of scale resorption. For instance, jack scales can be challenging when trying to apply resorption criteria because they often put on more growth in their last marine zone and appear to resorb scales at a different rate than older cohorts. Overall relative scale size is sometimes used to help identify jack scales. The decision-making process whether to add a year can therefore differ slightly between stocks as well as for different ages within stocks. Figure 14 reproduces the information and resorption criteria for different age types of Kitsumkalum Chinook scales. Other stocks will have different RS decision-making criteria. The SCL makes use of CWT information annually to corroborate the nuances of applying resorption criteria. If it works most of the time (~80%) the criteria is deemed valid.

2007 Kitsumkalum River Chinook Enumeration Keystream project (2007/177-180) CWT results were 59% agreement. Of 55 CWTs only 37 could be compared due to part/non-ages. Agreement was improved with some review of and update to criteria. Also, many of the books were fairly wet and were slightly under-pressed which led to incorrect identification of 1FWA's that were 0FWA. The adjustment in criteria is directed at jacks for which we have not had RS criteria before, and can be seen in updated RS Index table below. CWTs indicate that 2^3 index can be 1.1, but this can be difficult to determine especially when scale size is ambiguous. Therefore, these should be given a part-age. The other change is that if we have books this wet in future, especially in combination with a light press, we should be more cautious about assigning a FW age and assign more part ages. Once we had gone over the ages and changed our minds on a few, our agreement with the CWTs was 76%.

Age	Growth Index	Interpreted Age
1.1	≤2	1.1
1.1	2^3	1F
1.1	≥3^2	1.2
1.2	1-2	1.2
1.2	2-3	1.3
1.3	1	1.3
1.3	2-3	1.4
1.4	1	1.4
1.4	2-3	1.5

(07/11/29 SEM)

Figure 14. Excerpt from the SCL's Word document that records criteria for each stock's samples over time. Criteria (growth indices) are used to provide an interpreted age for Kitsumkalum Chinook scales that are resorbed and are of different visible ages. The first column is the visible age on the resorbed scale. The Growth Index is the measured size of the last growth zone relative to the previous year's growth. The interpreted age indicates if no or one year is added to the visible age or if some unknown amount of marine growth is missing, in which case a part age (FW age only) is given, e.g. 1F.

v) Disproportionate saltwater annual zones

Marine annual zones that are smaller or larger than expected in proportion to their placement within the overall scale growth pattern can be problematic, especially for the novice reader. This pattern may be common to certain stocks and affect a specific year of growth (e.g. 2nd or last marine) or may show up unexpectedly when fish experience atypical marine growth conditions (Fig. 15). These cases warrant documenting for future recognition and consistency in interpretation.

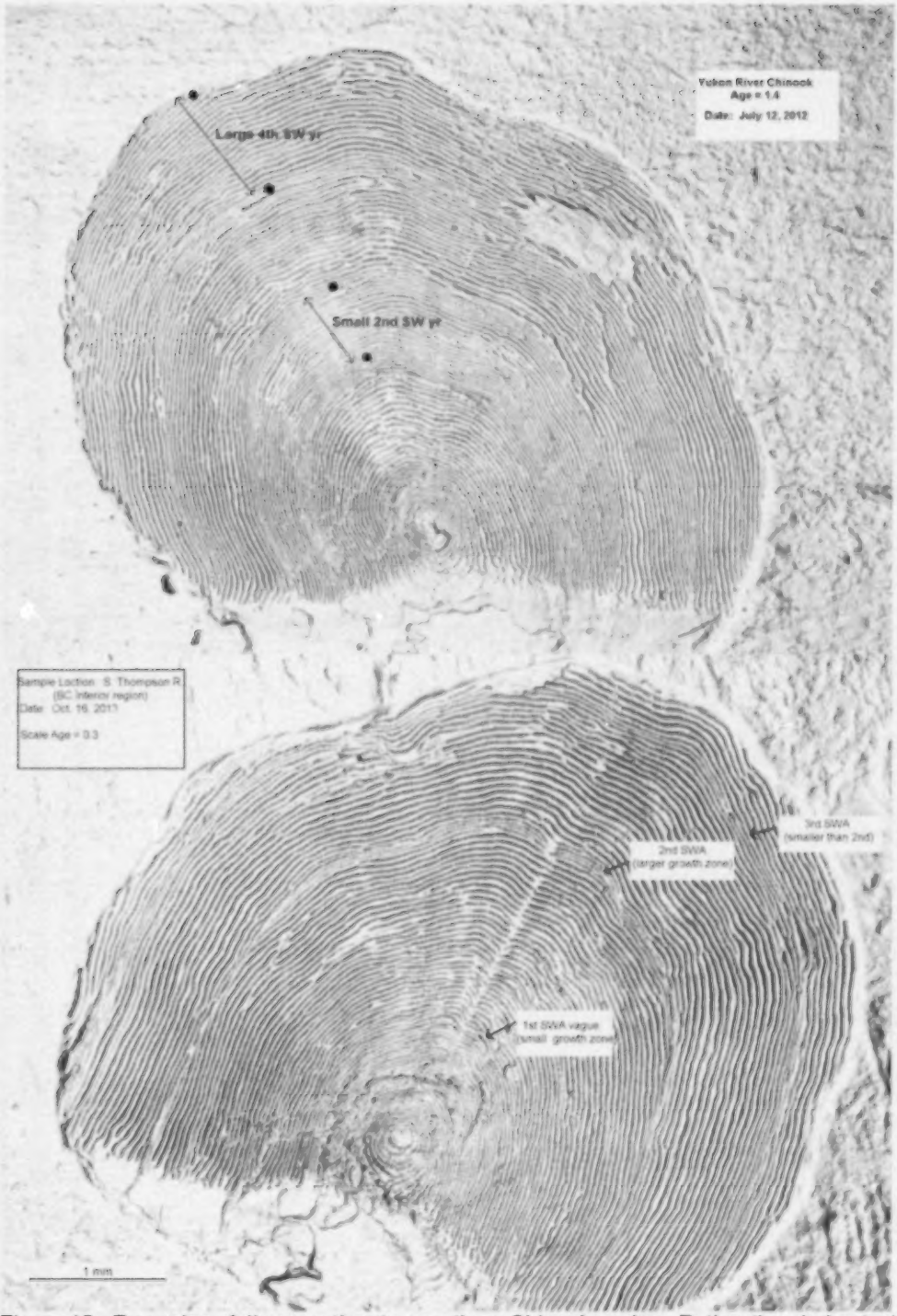
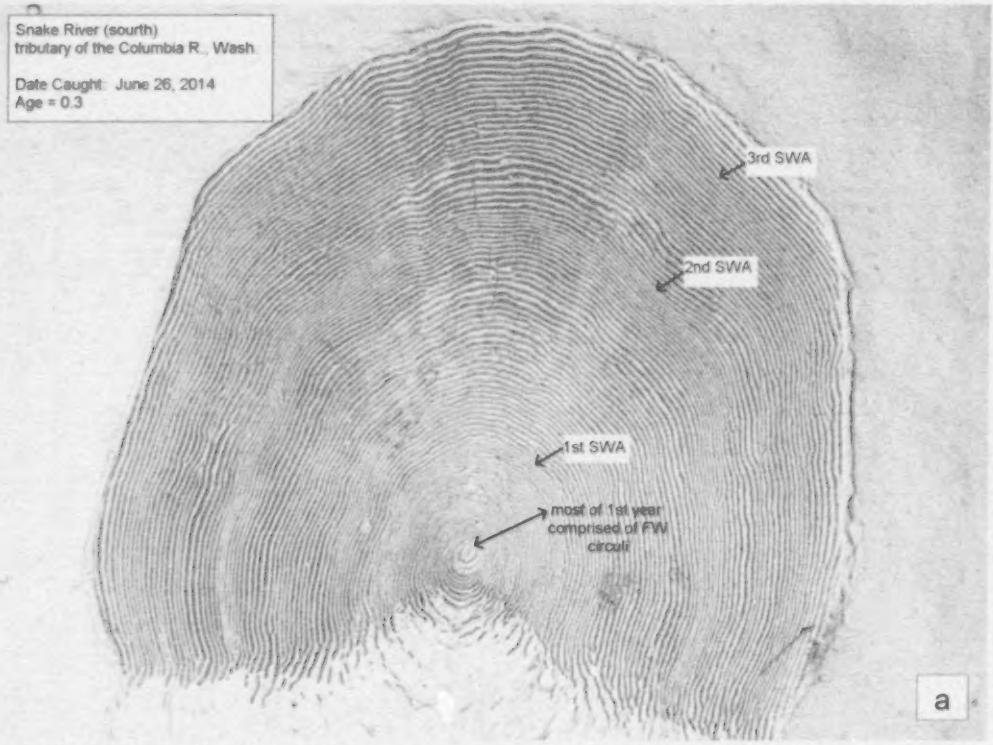


Figure 15. Examples of disproportionate growth on Chinook scales. Rather than being typically larger, the 2nd marine annual zone on the Yukon River scale and the 1st marine annual zone on the South Thompson scale are smaller than the next annual zone.

vi) Unfamiliar U.S.A. stocks in mixed fisheries

Ageing Chinook from mixed stock troll fisheries off the North/West coast of BC presents challenges. They contain a vast array of stocks of which a large component originates from US rivers that the SCL is not as familiar with as Canadian escapement and terminal fishery stocks. Many of these U.S. stocks originate from coastal/inland waters of Washington, Oregon and California. Some of the major US river systems such as the Columbia and Snake Rivers have dams on them that have been mitigated by large hatchery and salmon enhancement programs. These stocks have a plethora of growth patterns that are quite different from Canadian stocks and are challenging to age, even by our most experienced readers. Their scales generally have lots of FW circuli (>10) and prominent FW transition checks that can be easily misidentified as a FWA (Fig. 16). Through DNA stock identification information and scale exchanges with US readers the SCL has gained more experience and confidence with interpretation of these growth patterns. Scales from mixed fisheries are only aged by very experienced SCL readers familiar with interpreting foreign Chinook growth patterns.



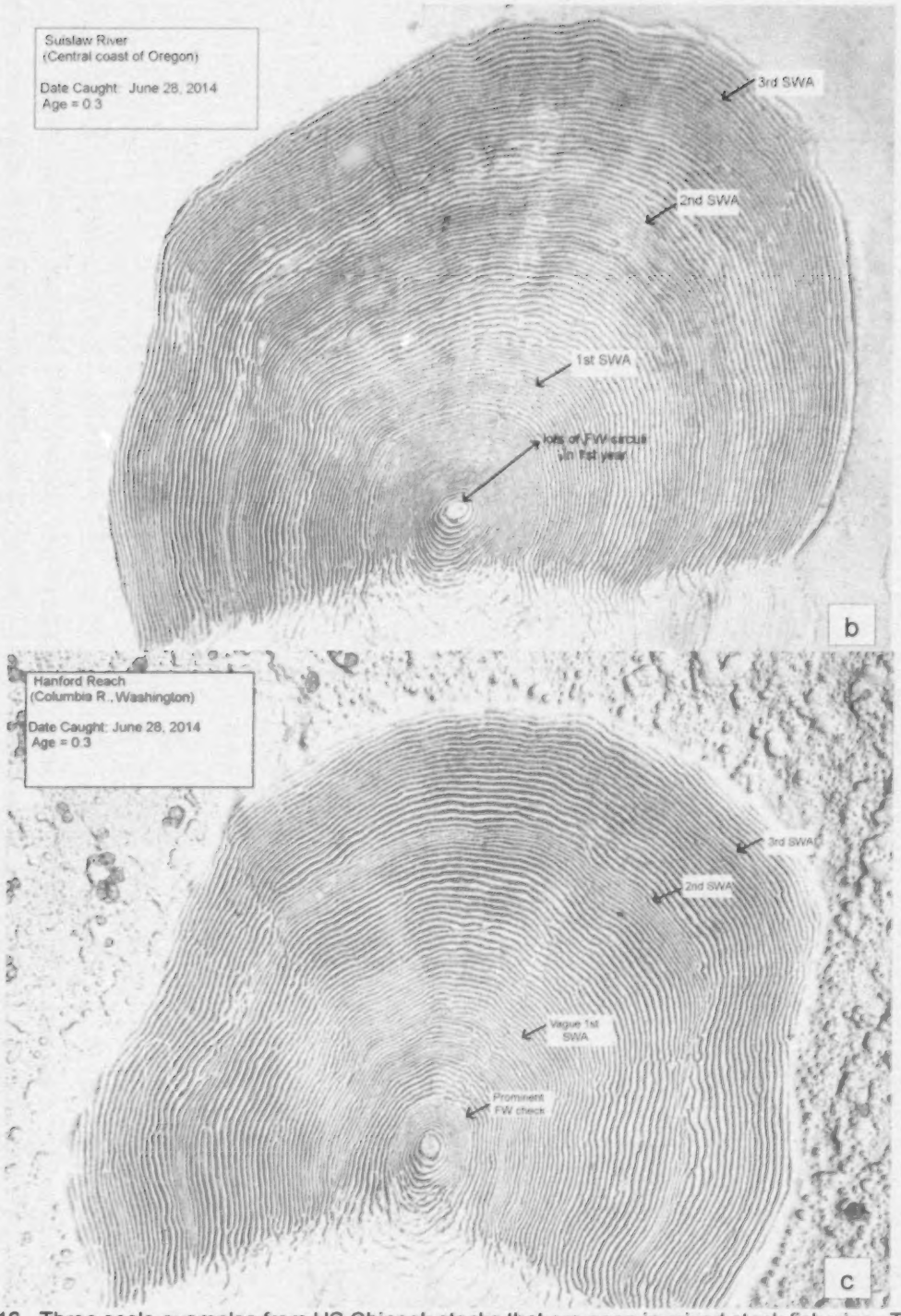


Figure 16. Three scale examples from US Chinook stocks that are seen in mixed stock fisheries. They represent growth patterns that are less familiar to SCL readers than Canadian stocks. The challenge is correctly deciding where the 1st SWA occurs and not counting large FW growth zones or prominent FW checks.

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GLOSSARY:

Accurate/accuracy measures the closeness to the true or actual age.

Age class refers to fish that were all born in the same calendar year.

Age designation systems denote how age is to be recorded for various species.

Age type refers to ocean- or stream-type age designations for salmonids that indicate the number of years spent in freshwater and saltwater.

An **annual growth zone** forms once a year. It is composed of a fast-growing summer zone followed by a slow-growing winter zone.

A scale **annulus (plural annuli)** is the last close-spaced circulus of the winter zone that forms during the "winter" months (fall/winter/early spring) representing a slowing of growth. By definition it forms only once a year.

Biases describe systematic differences in how readers apply ageing criteria and assign age to fish.

The **biological birthdate** is the actual time of the year that a fish hatches.

Blind ageing - see independent ageing.

A reader is considered to have **broad experience** when they have aged a wide variety of salmon species or stocks.

Capacity refers to the volume of work that the SCL can generate over time, e.g. a year, based on resources (trained staff) and effort required to age different species.

Checks may form within the summer zone and look very much like annuli. More than one may form per year and if prominent enough can be mistaken for annuli. They also represent a slowing of growth due to some kind of stress (usually unknown). Mistaking checks for annuli will lead to over-ageing.

Circuli are growth ridges that form on the exterior side of the anterior part of a salmon scale.

Coded wire tags (CWT) are tiny metal tags injected into the noses of salmon smolts that contain codes identifying hatchery, brood year and date of release.

Compound microscopes are high powered scopes (40X-1,000X) used to view small, two-dimensional specimens with transmitted light.

Continuity in age determination refers to long term consistency in how age is assessed for a species. This is usually achieved through documentation, training, standards, QA/QC systems, ergonomic practices and maintaining readers over the long term.

Age **criteria** are the rules developed, documented and employed to interpret annual growth patterns on scales in order to estimate age.

Cut out is term used to describe very densely packed dark-appearing freshwater annual zone.

Salmon sampled after death are referred to as **deadpitch**.

Dissecting microscopes are low powered scopes (1X-50X magnification) normally used to view relatively large three dimensional opaque specimens and may use either reflected or transmitted light.

A reader is considered to have **deep experience** if they have aged a significant number of salmon for a single species or stock over many years.

Edge growth forms on the margin of scales.

Expert status is granted to a reader that has demonstrated the ability to consistently meet precision and speed targets for both easy and difficult samples and maintains this status over the long term.

Ergonomic workstations and equipment physically ensure the health and longevity of readers.

Escapement samples are collected from mature fish found on freshwater spawning grounds.

The **final age** is the age generated by the SCL for a fish. This age is entered into databases and is used for analysis.

The **first (primary) reader** is the first reader to age a sample.

SCL readers **flag** specimens on their age data sheets that need a second non-independent opinion from another reader to resolve the age.

The first circulus to form in the centre of a scale is called the **focus**.

Independent (blind) ageing occurs when an additional reading of a fish is done without access to the first reading.

A **jack** is a precociously mature male Chinook salmon that over-winters only one year in the ocean and then returns to spawn.

The **January 1st birthdate** is the accepted standard birthdate used to assign age class rather than biological birthdate to fish in the northern hemisphere. All fish become one year older as of January 1st. This keeps fish born in the same calendar year grouped together for assessment and management purposes.

Known-age/part known-age refers to fish where the total or part of the actual or true age is known because of some process (ex. tagging or marking) that has established the annual regularity of growth zone deposition and/or the calendar year of birth.

Life history type refers to whether a salmon spends a winter(s) in freshwater (stream-type) or not (ocean-type) before smolting and going to sea.

The **margin/edge** refers to the outer circumference of a scale where new growth forms.

Non-independent ages are produced when readers have access to ages generated by other readers.

Ocean-type life history Chinook go to sea during their first year of life.

Pacific Age Database System (**PADS**) is a central Oracle database used by the SCL to record salmon age data.

Part known-age (see known-age).

Percent agreement calculates agreement of age data between 2 readers, within a reader or reader against known-age samples.

Precision measures repeatability or consistency. Age estimates for the same fish can be compared within/without readers or agencies.

Precision tests are a quality control tool where independent (blind) tests are carried out to assess the repeatability of readings (ages).

Primary reader – see first reader.

Production ageing refers to the long term routine age determination of large numbers of samples for stock assessment purposes.

Productivity refers to the number of fish per hour a reader can age.

A **Quality Assurance (QA) system** consists of planned, documented and systematic procedures developed to demonstrate confidence in the age data quality and/or to confirm that the data conforms to specified requirements.

Quality Control (QC) is part of the QA system and is the responsibility of everyone in the program. QC is a specific process to test results against set standards and the actions taken when there are discrepancies.

Reader biases exist when a reader is prone to choosing certain ages/age types over others when faced with indecision, e.g. older or younger, stream- or ocean-type.

Reader drift occurs when a reader changes how they apply age criteria resulting in discontinuity of age data over time.

SCL **reader rates** represent the number of fish that a reader can age in an hour.

Reference collections are specifically chosen samples that are set aside and maintained to test and train readers over time to prevent reader drift.

Reflected light is directed down onto a specimen that is placed under a microscope objective.

Regenerate scales are missing circuli from the focal area caused by loss of the original scale. This results in a blank space in the central area of the scale pattern that affects the reader's ability to provide an accurate age.

The **resolution process** occurs when a reader works to decide amongst differing multiple ages generated for one specimen, narrowing it down to a single age. This process usually involves at least 2 readers or readings.

Resorbed scale (see resorption).

Scale **resorption** occurs during the migration of spawning salmon. Physiological processes break down the edges/margins of scales resulting in the loss of growth zones.

Scale books are used to collect SCL salmon scale samples in the field. They consist of a gummed card with a grid of 50 squares to mount the scales.

SCL is the acronym for the Sclerochronology Lab program.

When a sample is **second read** a second reader will read the whole sample through having access to the first reader's ages, i.e. is not an independent reading.

The **second reader (tester)** is the next reader to age a subsample of the first reader's sample via a precision test.

Self-precision measures agreement of independent multiple readings by the same reader.

Spring plus growth is a band of freshwater circuli that forms in the new year, after a freshwater annulus, and represents a short time spent in freshwater before smolting.

Summer zone is the growth zone on scales that forms during the fast-growing seasons of late spring, summer and early fall. Only one summer zone forms per year, but it may be broken up by the presence of one or more checks.

Sclerochronology is the study of the physical and chemical variations in the accretionary process of hard tissues, and the temporal context in which they are formed. In the context of fish age estimation these include otoliths, fin/dorsal rays, vertebrae and scales.

Stream-type life history Chinook spend at least one winter in freshwater.

Technical competencies such as accuracy, precision and productivity are measured by the SCL to assess and monitor a reader's skill level.

Tester – see second reader.

Transmitted light is directed upwards through a specimen that is placed on a microscope stage.

Validation of an ageing method occurs through the use of known-age specimens via a variety of techniques such CWTs. CWTs verify the accuracy of the salmon scale ageing method for hatchery fish.

The **winter zone** on scales is the growth zone that forms during the slow-growing seasons of late fall, winter and early spring. Only one winter zone forms per year. It consists of thinner and consecutively more narrow-spaced circuli with the annulus being the last close-spaced circulus of the zone.

Working columns are found on SCL age data sheets. Readers record age estimates for each scale for a fish in these columns. A series of working columns are available to record the results of multiple readings including precision test results and other readings needed to resolve differences.

A **year class** indicates the calendar year of birth. Strong year class information can be useful yet biasing when estimating age of fish samples.

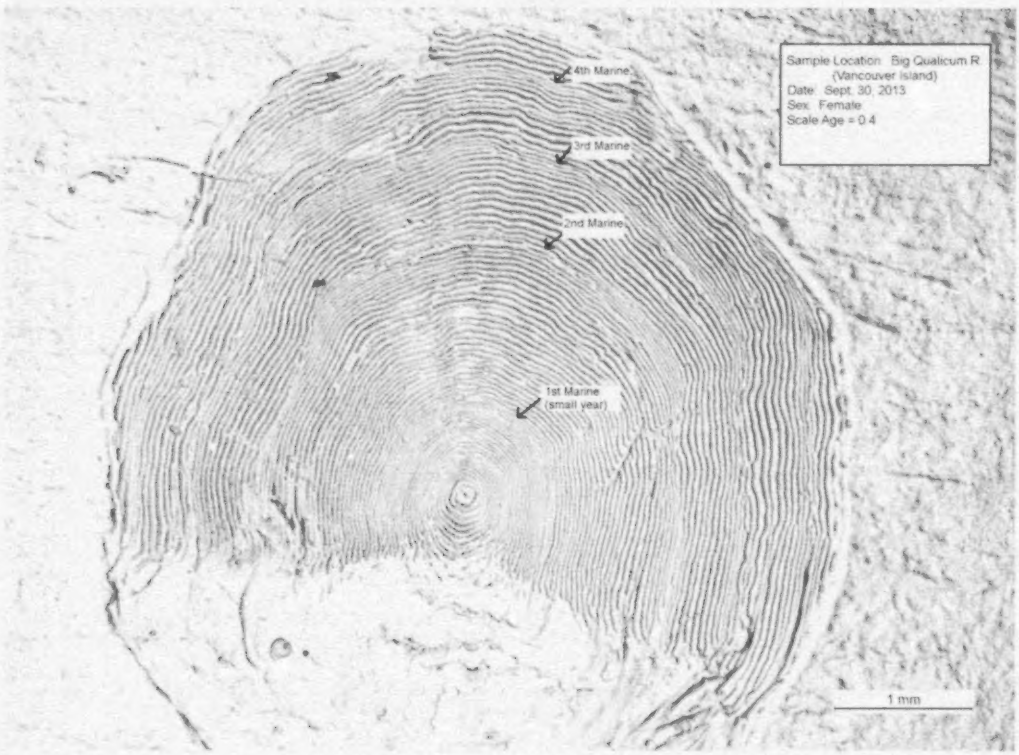
The **year of life** refers to the year a salmon migrates to sea or back to freshwater. It is not the same as age or age class. For example, a fish in its third year of life is not 3 years old. It is 2 years old and will not be 3 until it lives past its third January 1st birthday.

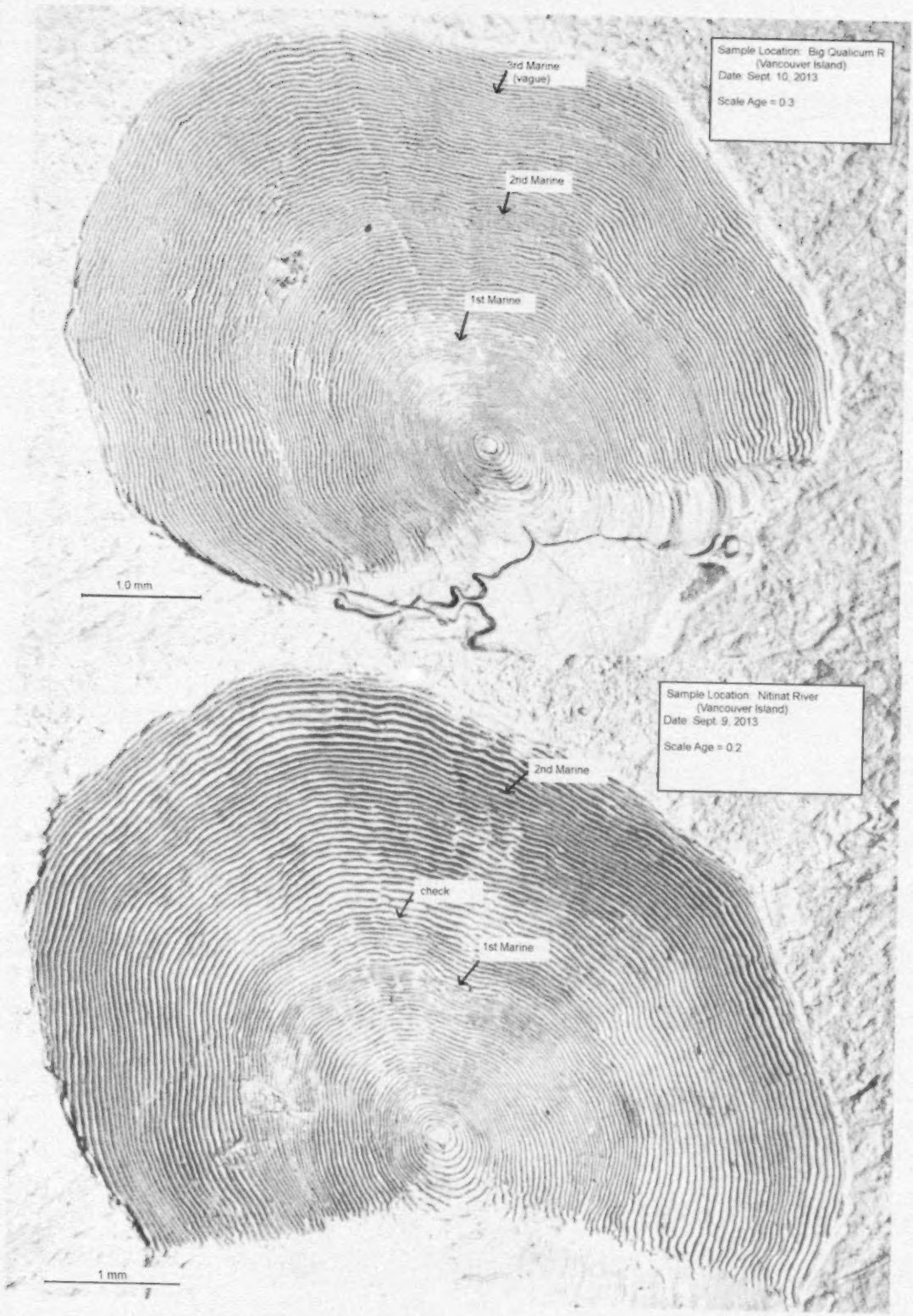
APPENDICES:

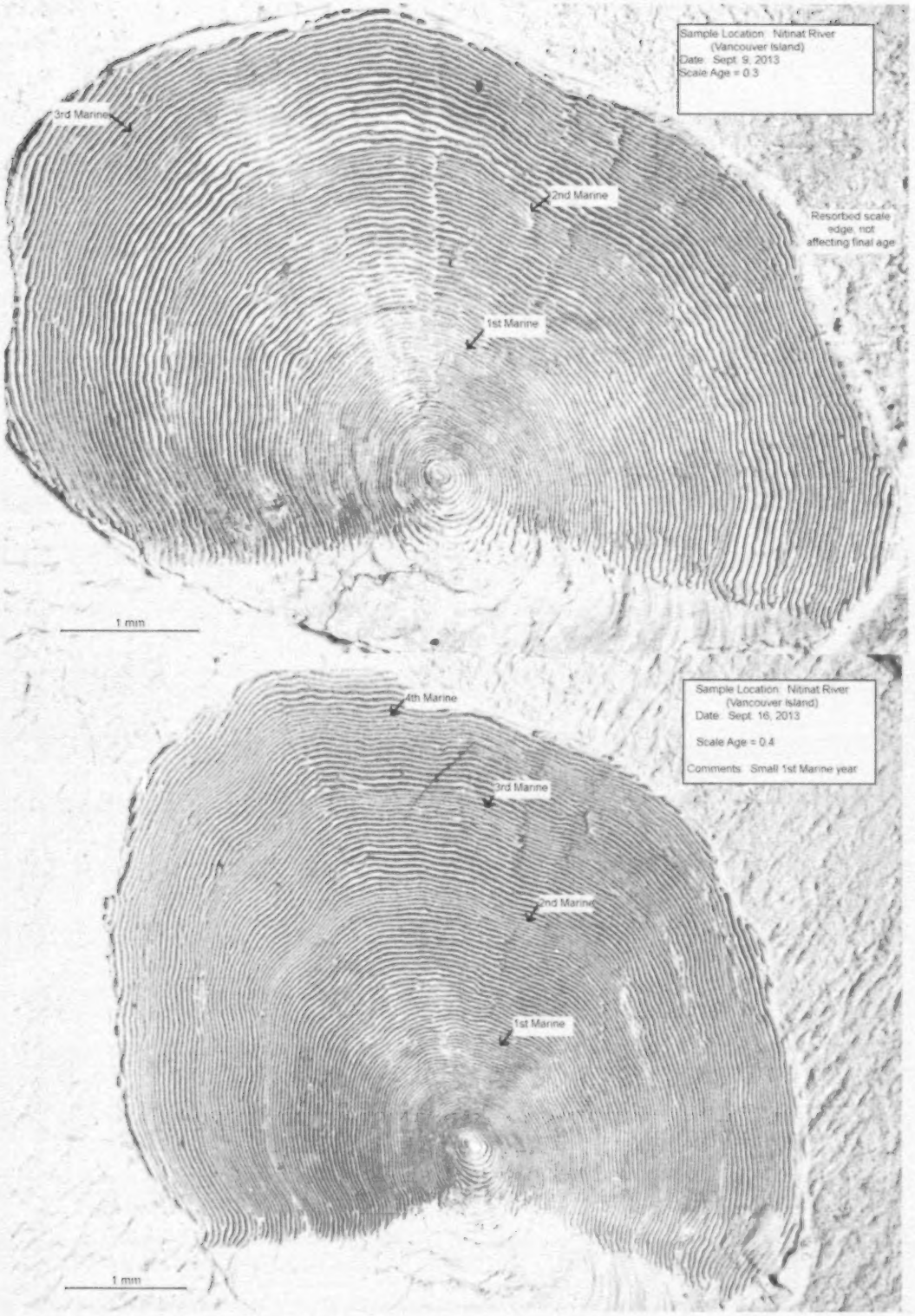
Appendix 1

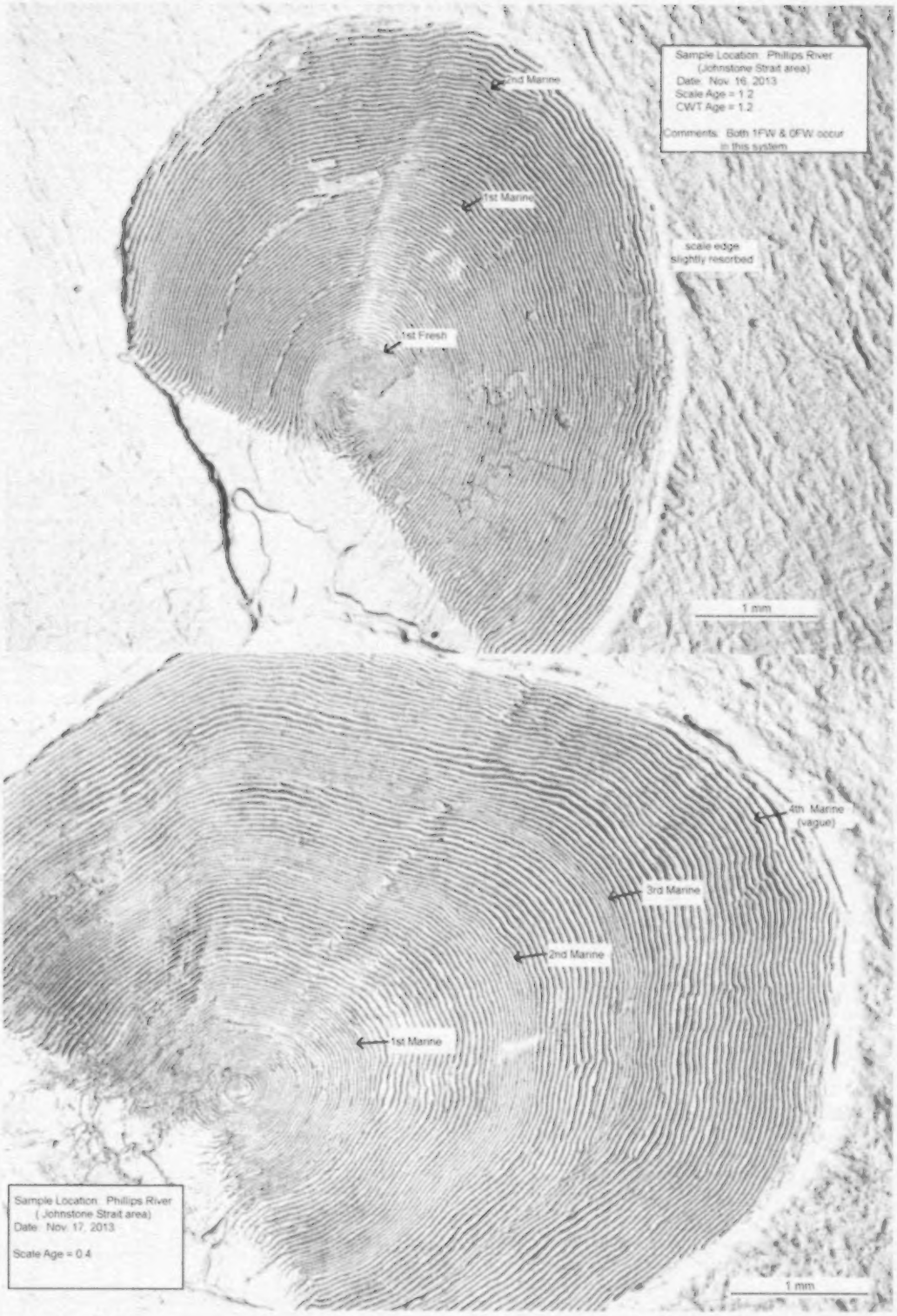
Representative Scale Patterns from some major rivers within BC & the Yukon by Region

BC South Coast & Vancouver Island:

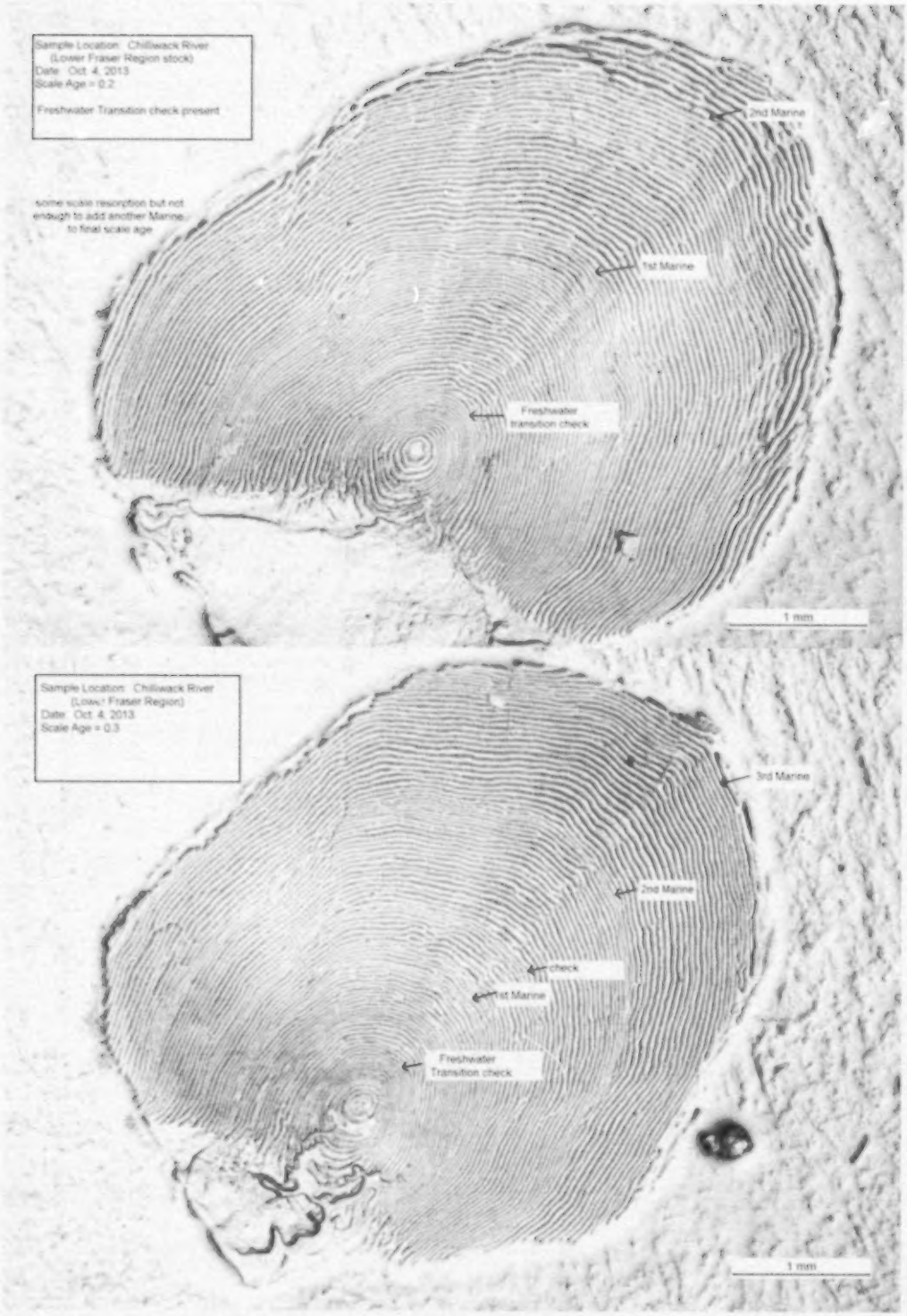


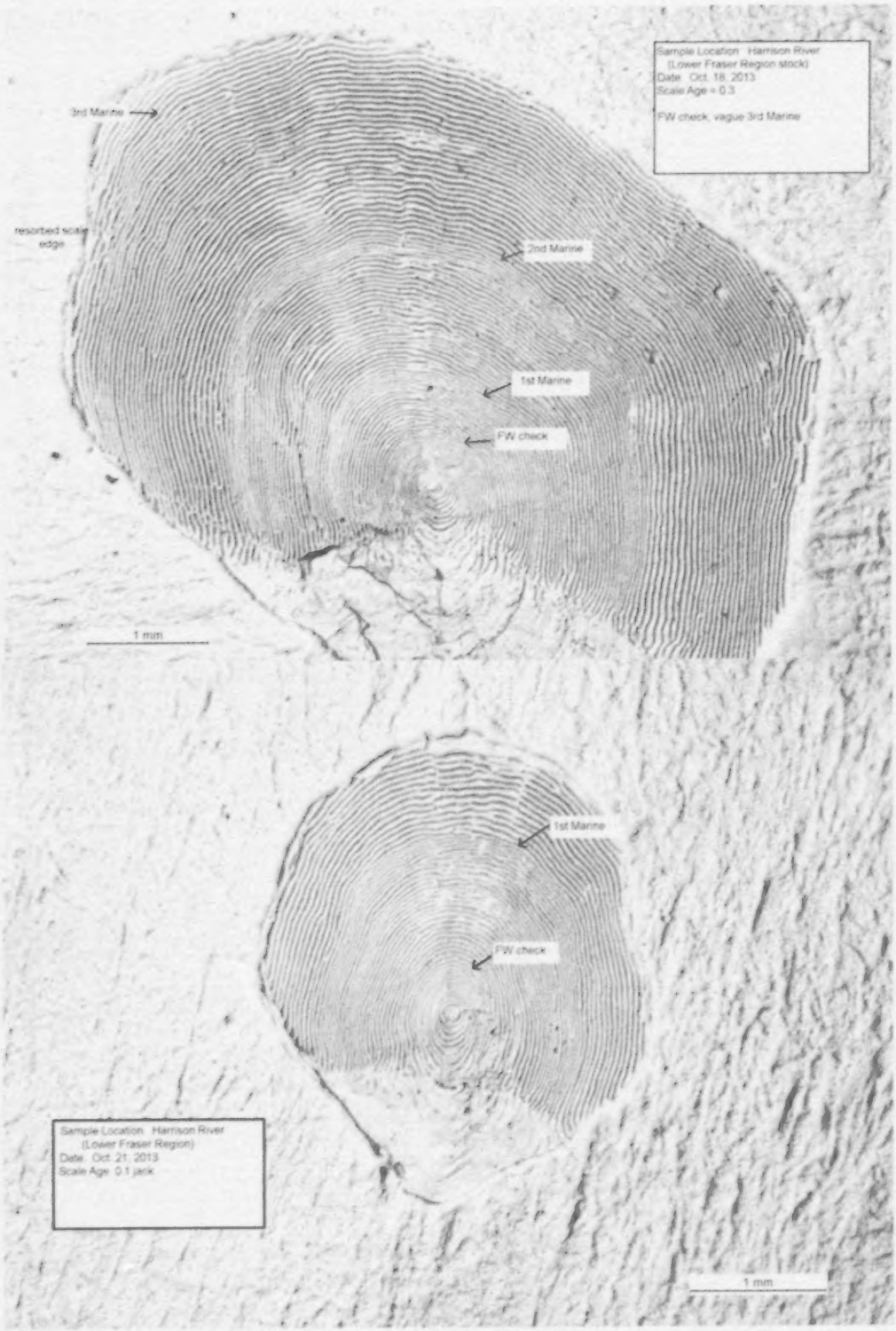

Sample Location: Big Qualicum R.
(Vancouver Island)
Date: Sept. 10, 2013
Scale Age = 0.3
3rd Marine
(vague)
2nd Marine
1st Marine
1.0 mm
Sample Location: Nitinat River
(Vancouver Island)
Date: Sept. 9, 2013
Scale Age = 0.2
2nd Marine
check
1st Marine
1 mm


Sample Location: Nitinat River (Vancouver Island)
Date: Sept. 9, 2013
Scale Age = 0.3
3rd Marine
2nd Marine
Resorbed scale edge, not affecting final age
1st Marine
1 mm
Sample Location: Nitinat River (Vancouver Island)
Date: Sept. 16, 2013
Scale Age = 0.4
Comments: Small 1st Marine year
4th Marine
3rd Marine
2nd Marine
1st Marine
1 mm

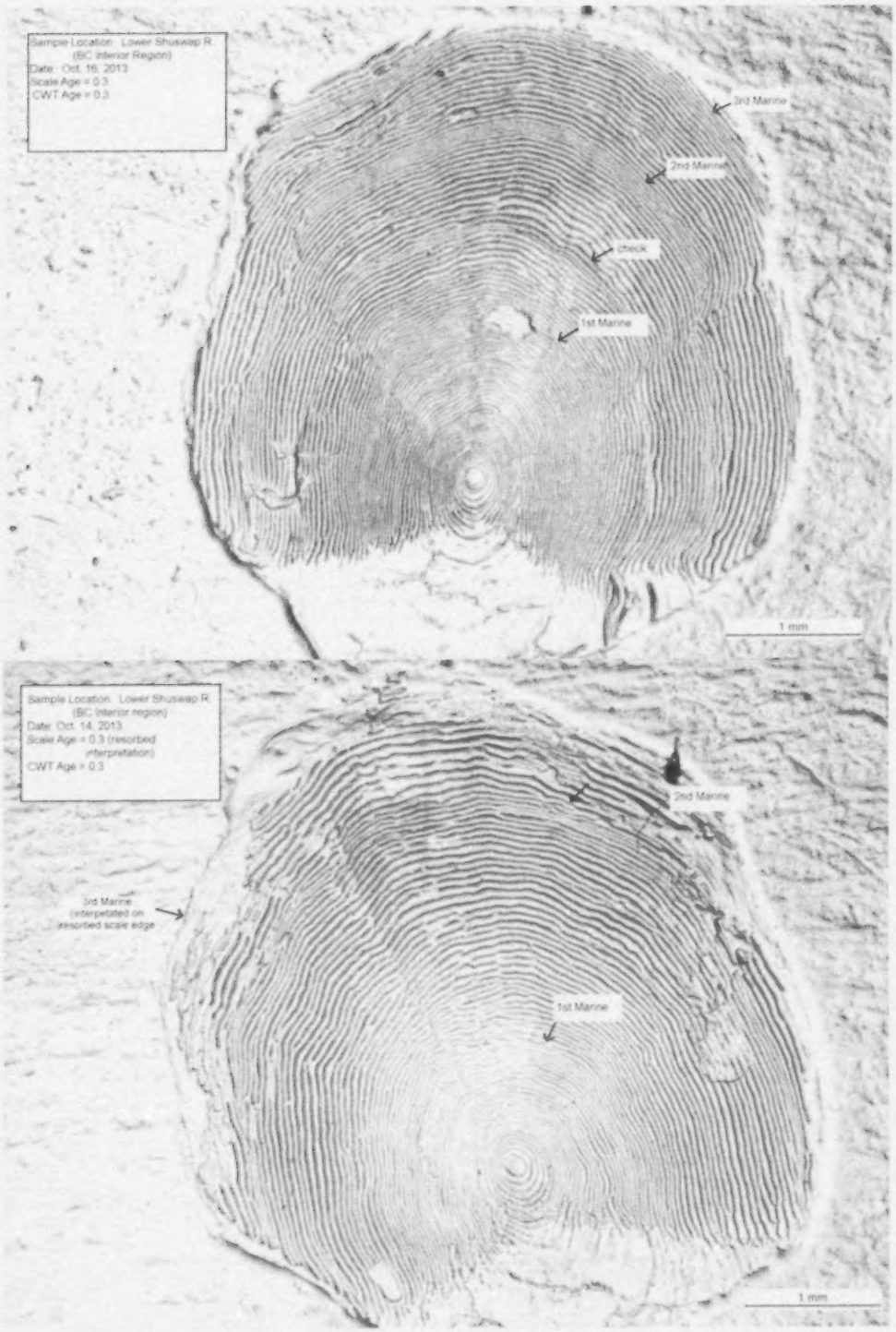

Sample Location: Phillips River
(Johnstone Strait area)
Date: Nov. 16, 2013
Scale Age = 1.2
CWT Age = 1.2
Comments: Both 1FW & 0FW occur
in this system
2nd Marine
1st Marine
1st Fresh
scale edge
slightly resorbed
1 mm
4th Marine
(vague)
3rd Marine
2nd Marine
1st Marine
Sample Location: Phillips River
(Johnstone Strait area)
Date: Nov. 17, 2013
Scale Age = 0.4
1 mm

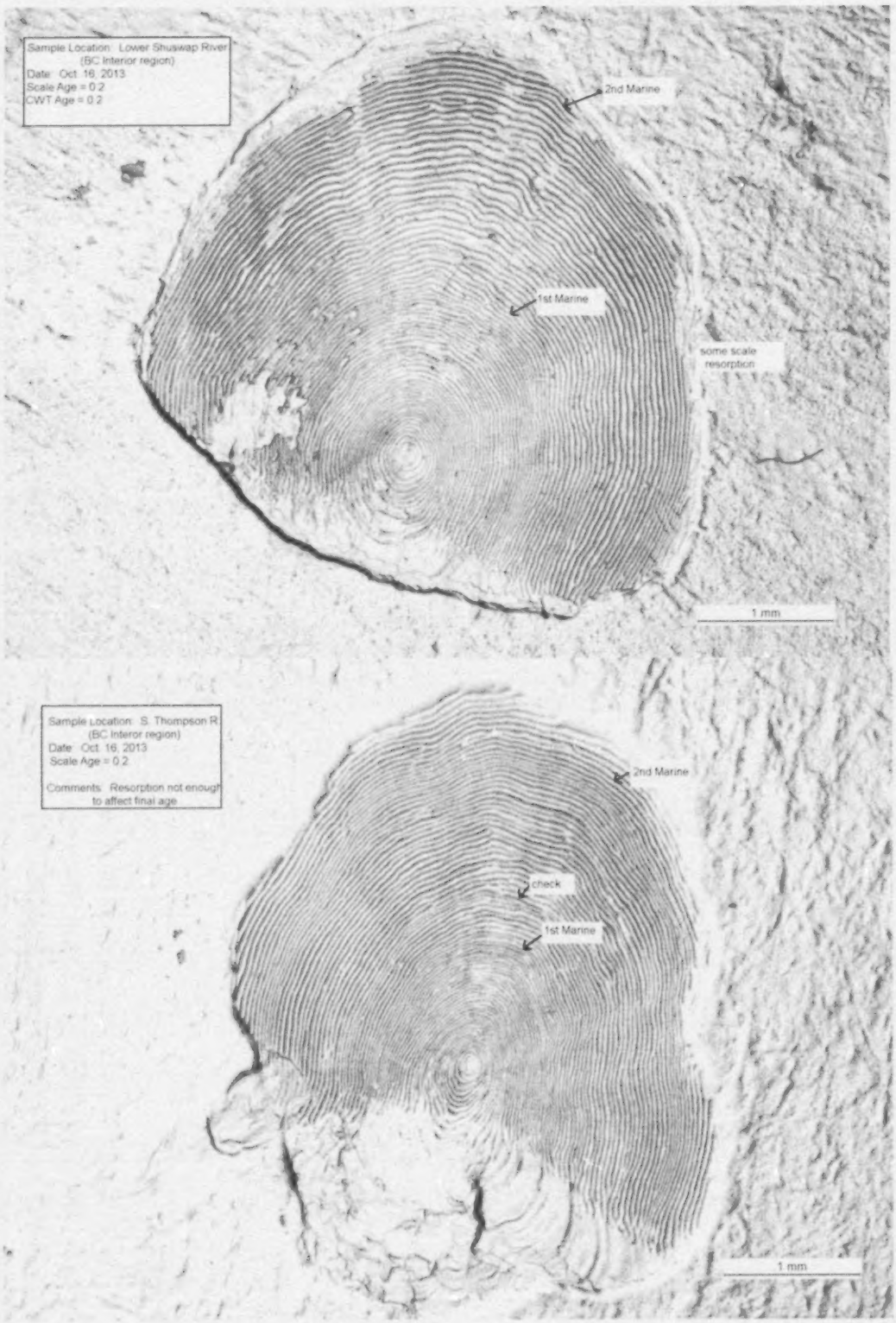
Lower Fraser:

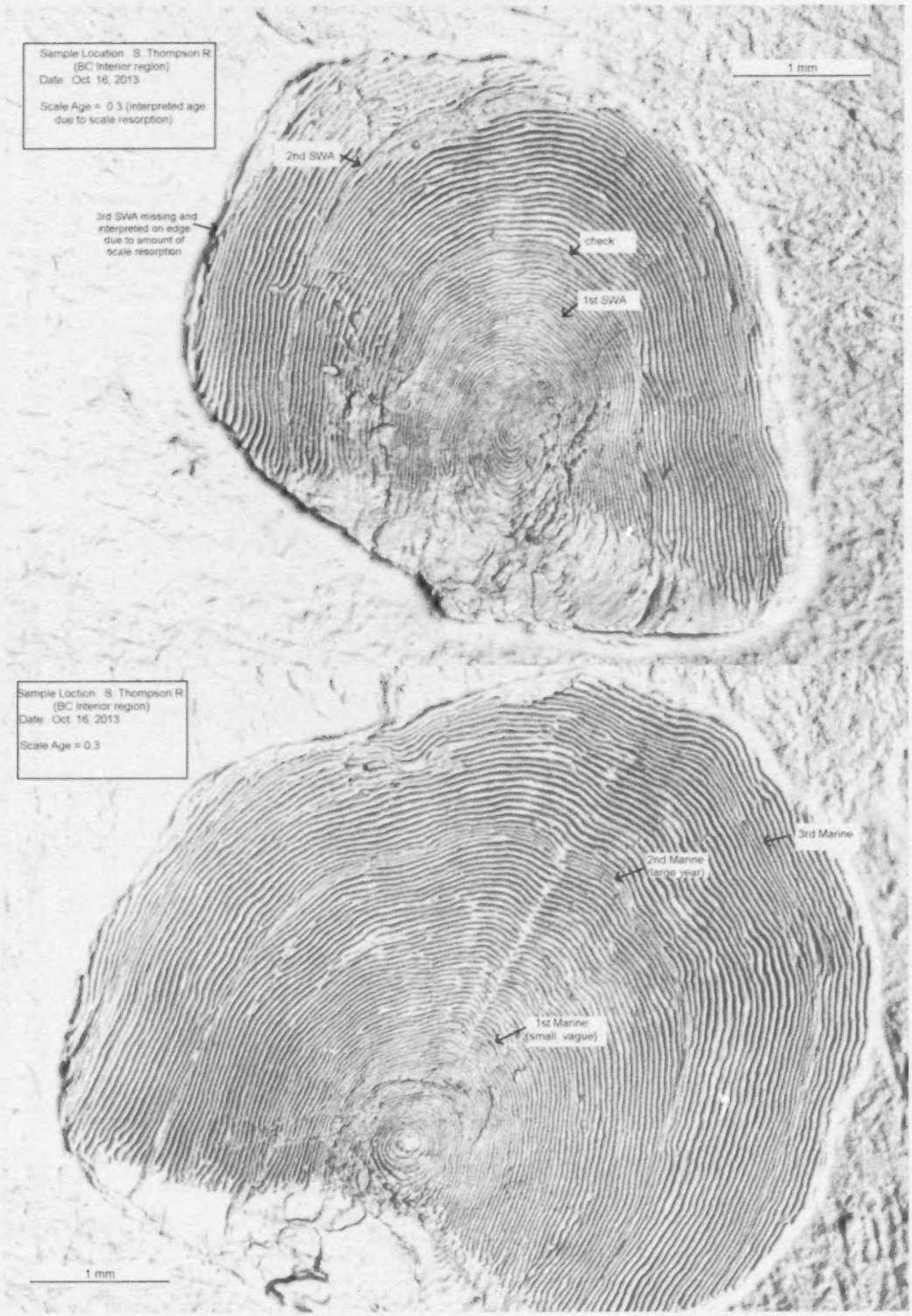


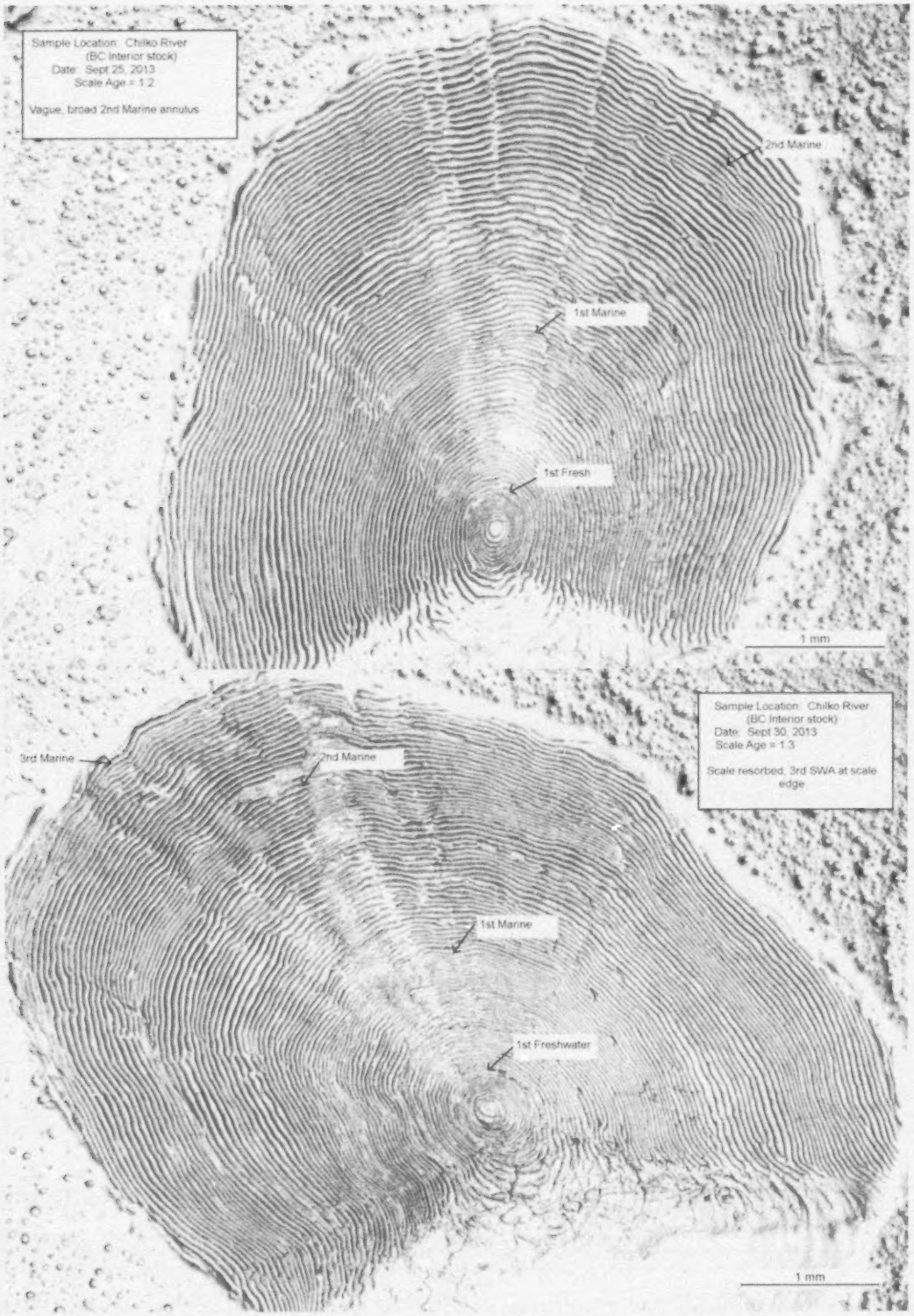

Sample Location: Harrison River
(Lower Fraser Region stock)
Date: Oct. 18, 2013
Scale Age = 0.3
FW check, vague 3rd Marine
3rd Marine
resorbed scale edge
2nd Marine
1st Marine
FW check
1 mm
1st Marine
FW check
Sample Location: Harrison River
(Lower Fraser Region)
Date: Oct. 21, 2013
Scale Age: 0.1 jack
1 mm

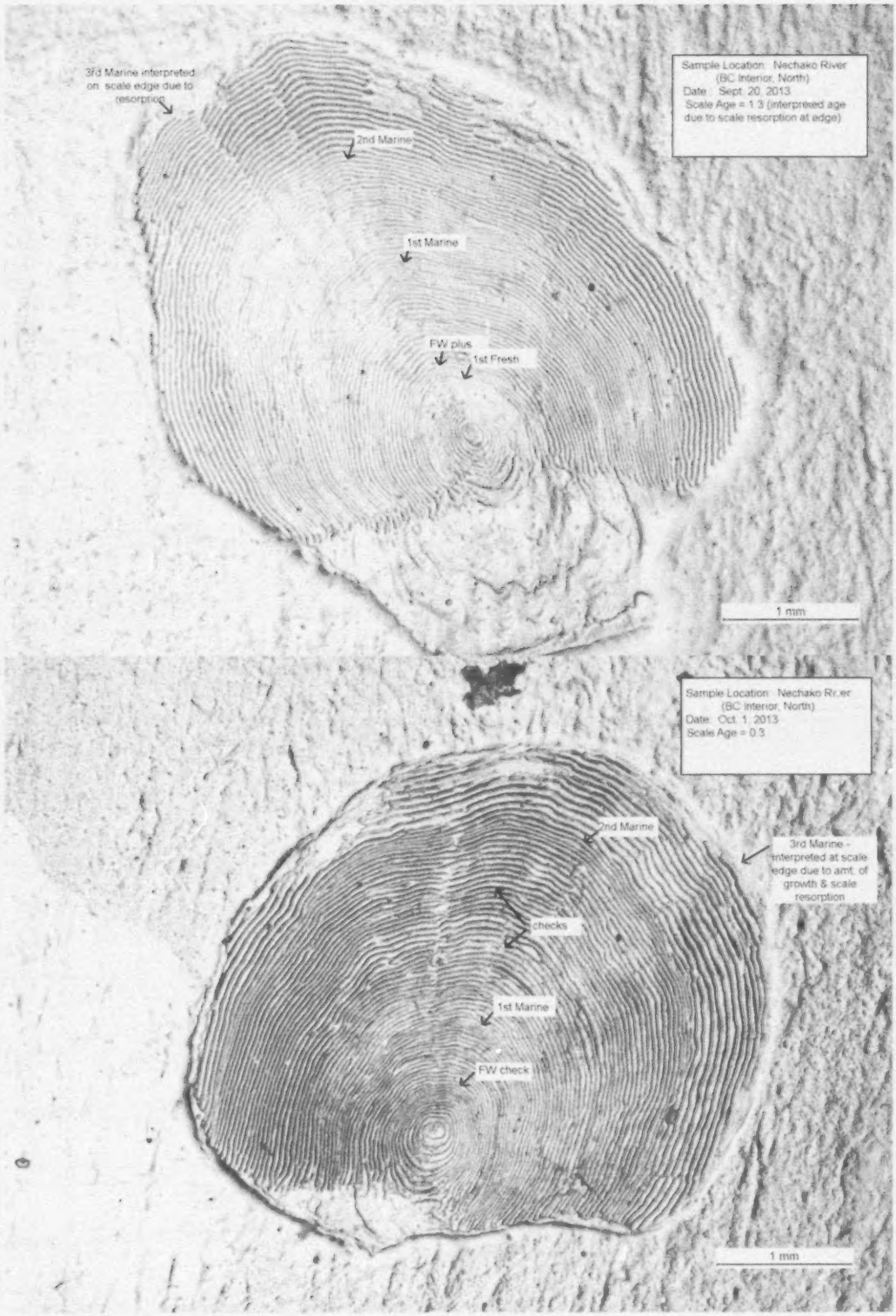
BC Interior:


Sample Location: Lower Shuswap R.
(BC Interior Region)
Date: Oct. 16, 2013
Scale Age = 0.3
CWT Age = 0.3
3rd Marine
2nd Marine
check
1st Marine
1 mm
Sample Location: Lower Shuswap R.
(BC Interior region)
Date: Oct. 14, 2013
Scale Age = 0.3 (resorbed interpretation)
CWT Age = 0.3
2nd Marine
3rd Marine (interpetated on resorbed scale edge
1st Marine
1 mm

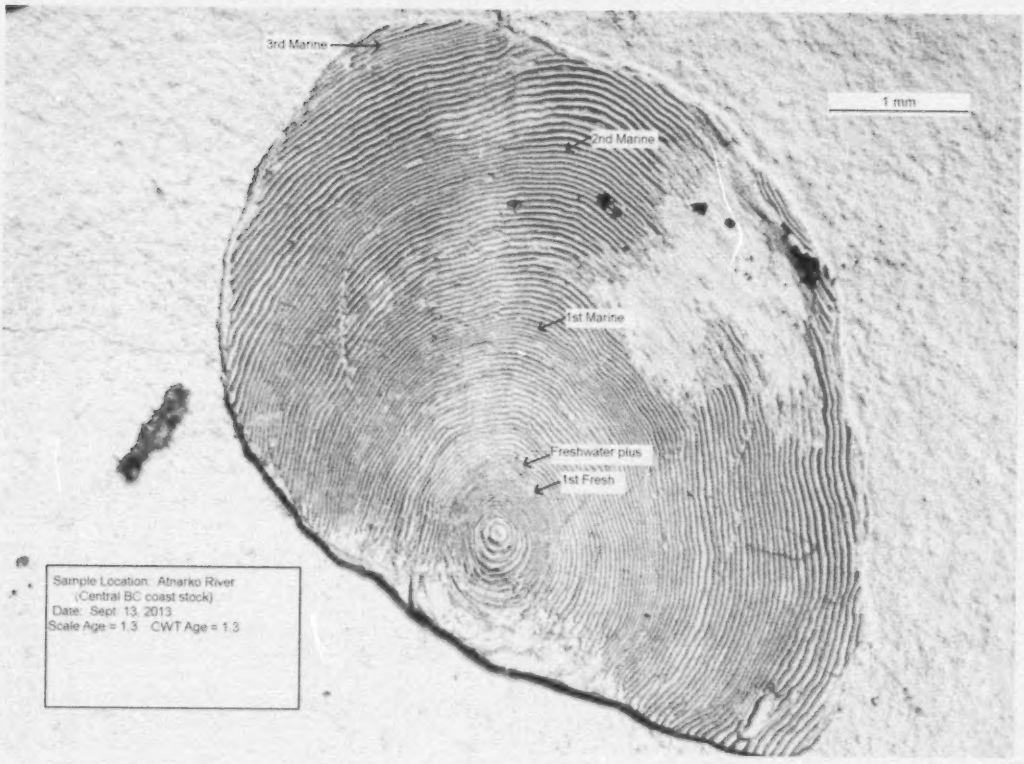

Sample Location: Lower Shuswap River
(BC Interior region)
Date: Oct. 16, 2013
Scale Age = 0.2
CWT Age = 0.2
2nd Marine
1st Marine
some scale
resorption
1 mm
Sample Location: S. Thompson R.
(BC Interor region)
Date: Oct. 16, 2013
Scale Age = 0.2
Comments: Resorption not enough
to affect final age
2nd Marine
check
1st Marine
1 mm

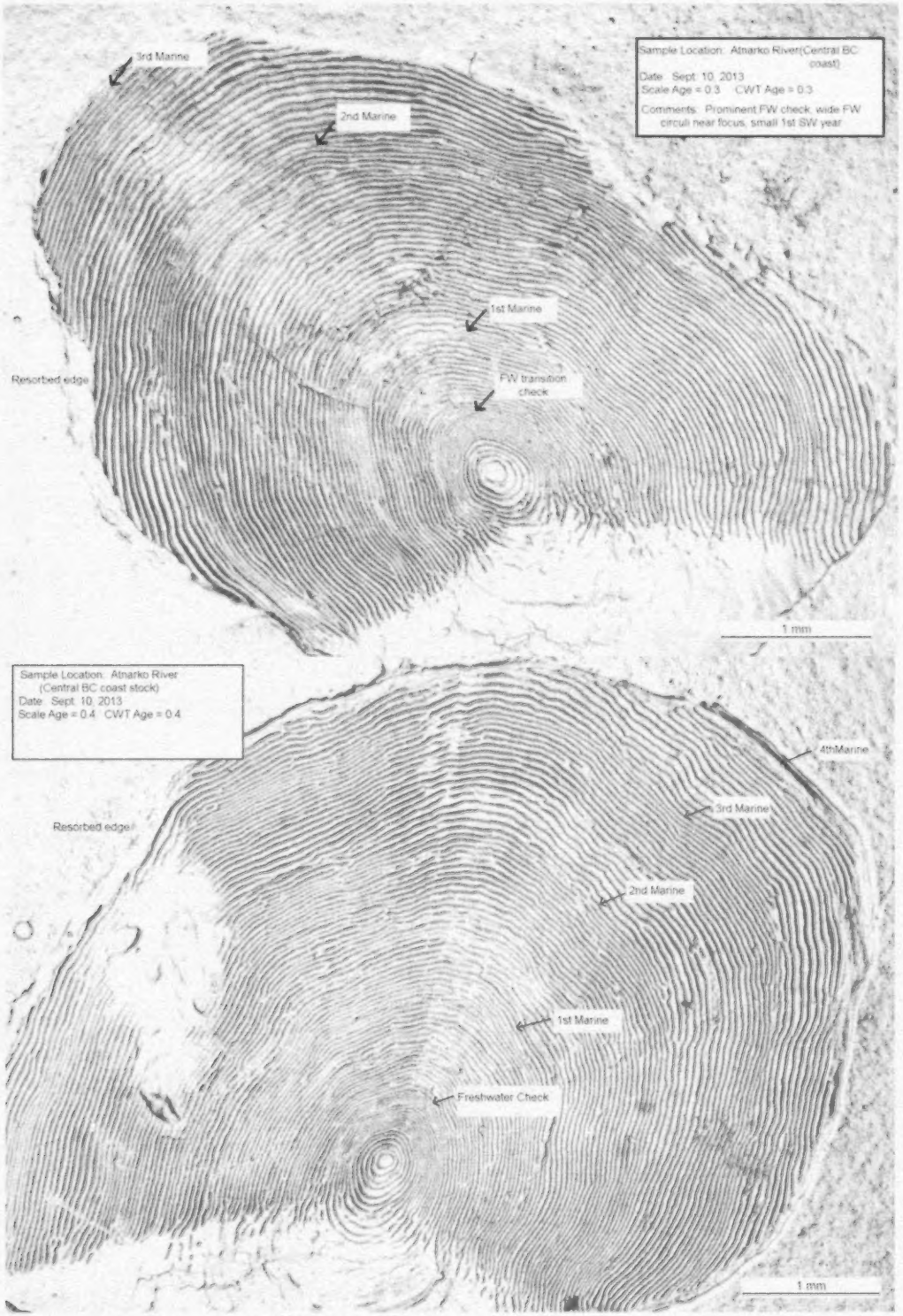

Sample Location: S. Thompson R
(BC Interior region)
Date: Oct. 16, 2013
Scale Age = 0.3 (interpreted age due to scale resorption)
1 mm
2nd SWA
3rd SWA missing and interpreted on edge due to amount of scale resorption
check
1st SWA
Sample Loction: S. Thompson R
(BC Interior region)
Date: Oct. 16, 2013
Scale Age = 0.3
3rd Marine
2nd Marine (large year)
1st Marine (small, vague)
1 mm


Sample Location: Chilko River
(BC Interior stock)
Date: Sept 25, 2013
Scale Age = 1.2
Vague, broad 2nd Marine annulus
2nd Marine
1st Marine
1st Fresh
1 mm
Sample Location: Chilko River
(BC Interior stock)
Date: Sept 30, 2013
Scale Age = 1.3
Scale resorbed, 3rd SWA at scale edge
3rd Marine
2nd Marine
1st Marine
1st Freshwater
1 mm

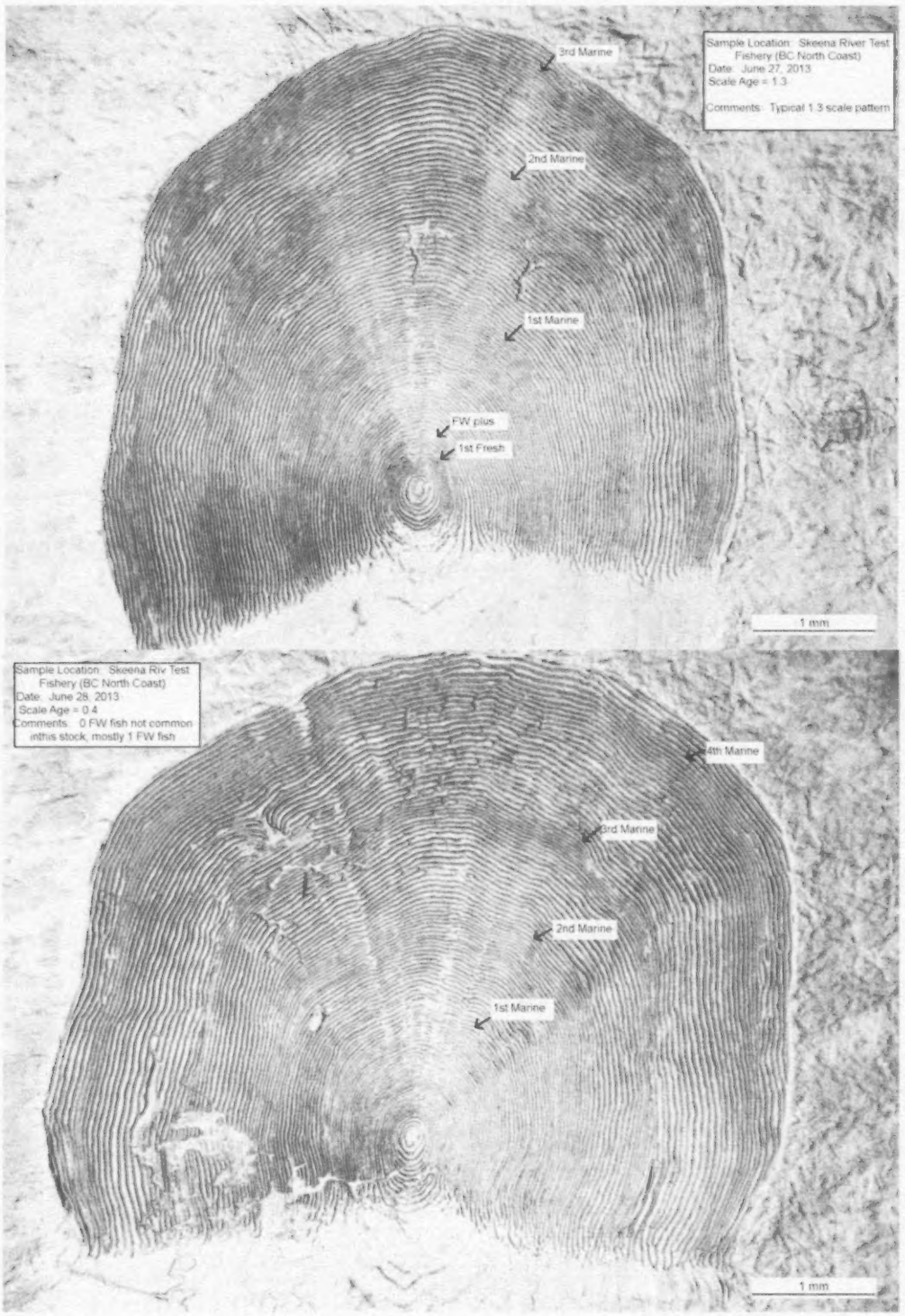

3rd Marine interpreted on scale edge due to resorption
2nd Marine
1st Marine
FW plus
1st Fresh
Sample Location: Nechako River (BC Interior, North)
Date: Sept. 20, 2013
Scale Age = 1.3 (interpreted age due to scale resorption at edge)
1 mm
Sample Location: Nechako River (BC Interior, North)
Date: Oct. 1, 2013
Scale Age = 0.3
2nd Marine
3rd Marine - interpreted at scale edge due to amt. of growth & scale resorption
checks
1st Marine
FW check
1 mm

BC Central Coast:

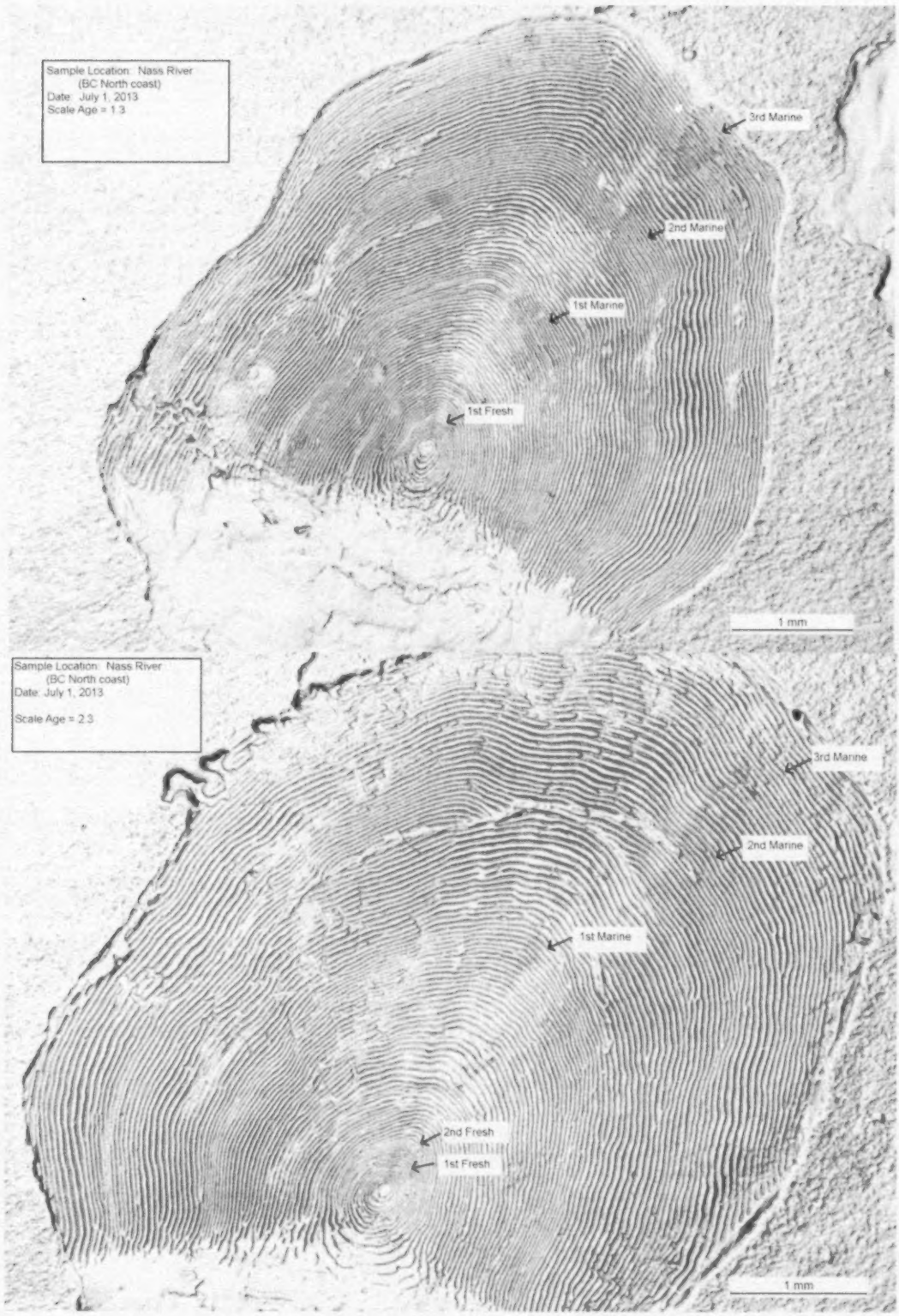


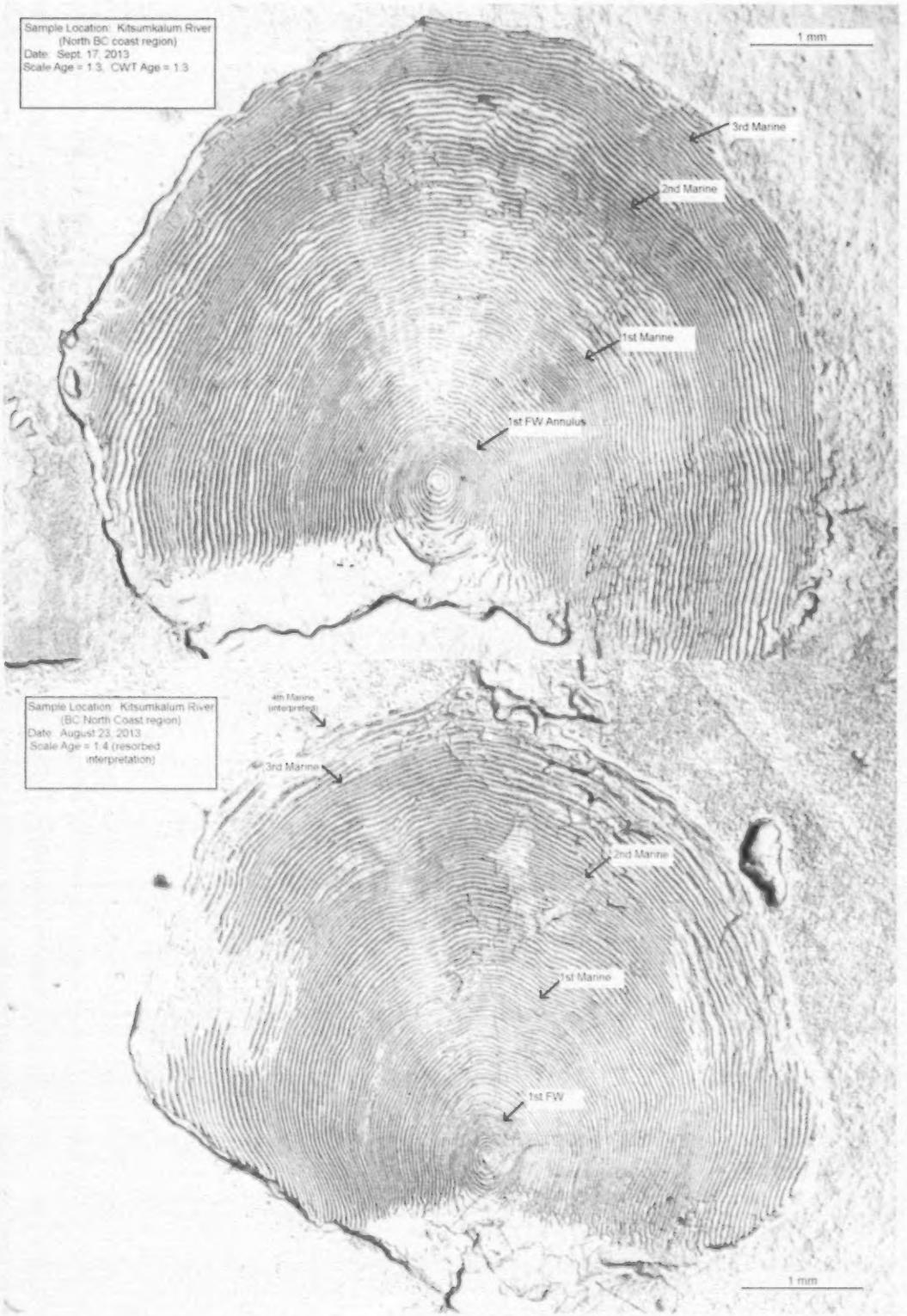

3rd Marine
2nd Marine
Sample Location: Atnarko River(Central BC coast)
Date: Sept. 10, 2013
Scale Age = 0.3 CWT Age = 0.3
Comments: Prominent FW check, wide FW circuli near focus, small 1st SW year
1st Marine
Resorbed edge
FW transition check
1 mm
Sample Location: Atnarko River (Central BC coast stock)
Date: Sept. 10, 2013
Scale Age = 0.4 CWT Age = 0.4
4thMarine
3rd Marine
Resorbed edge
2nd Marine
1st Marine
Freshwater Check
1 mm

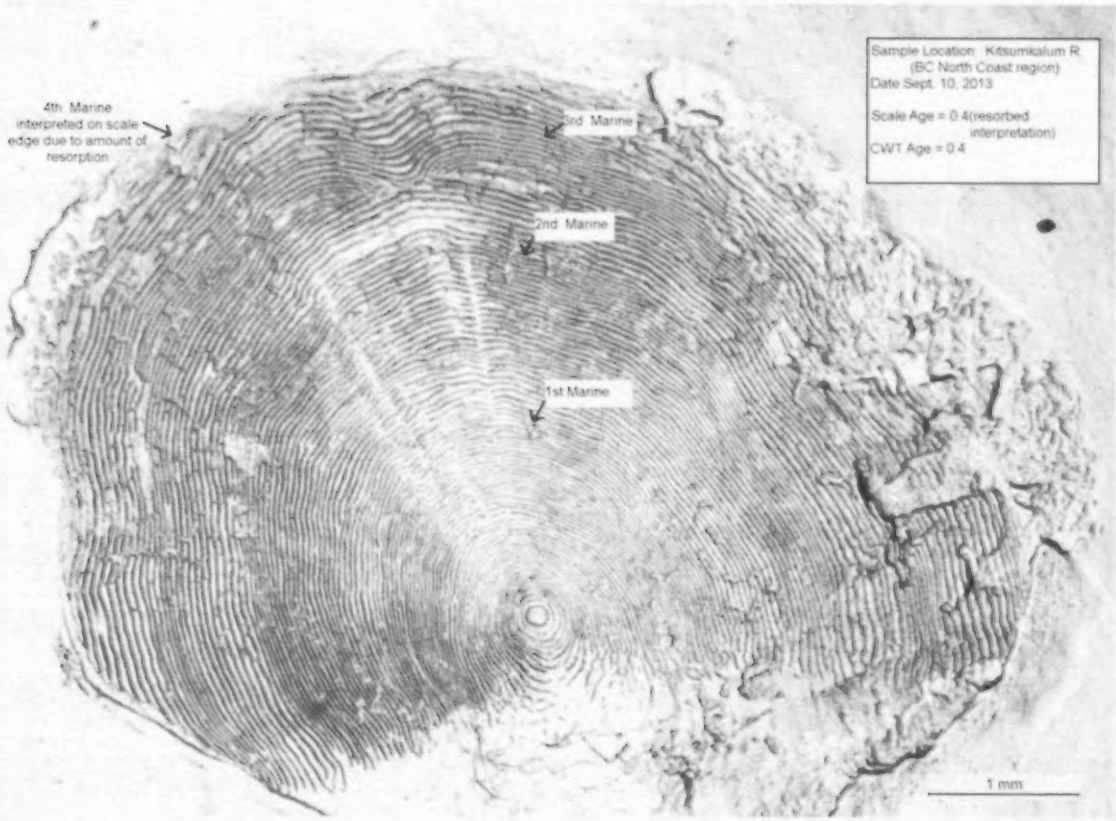
BC North Coast:



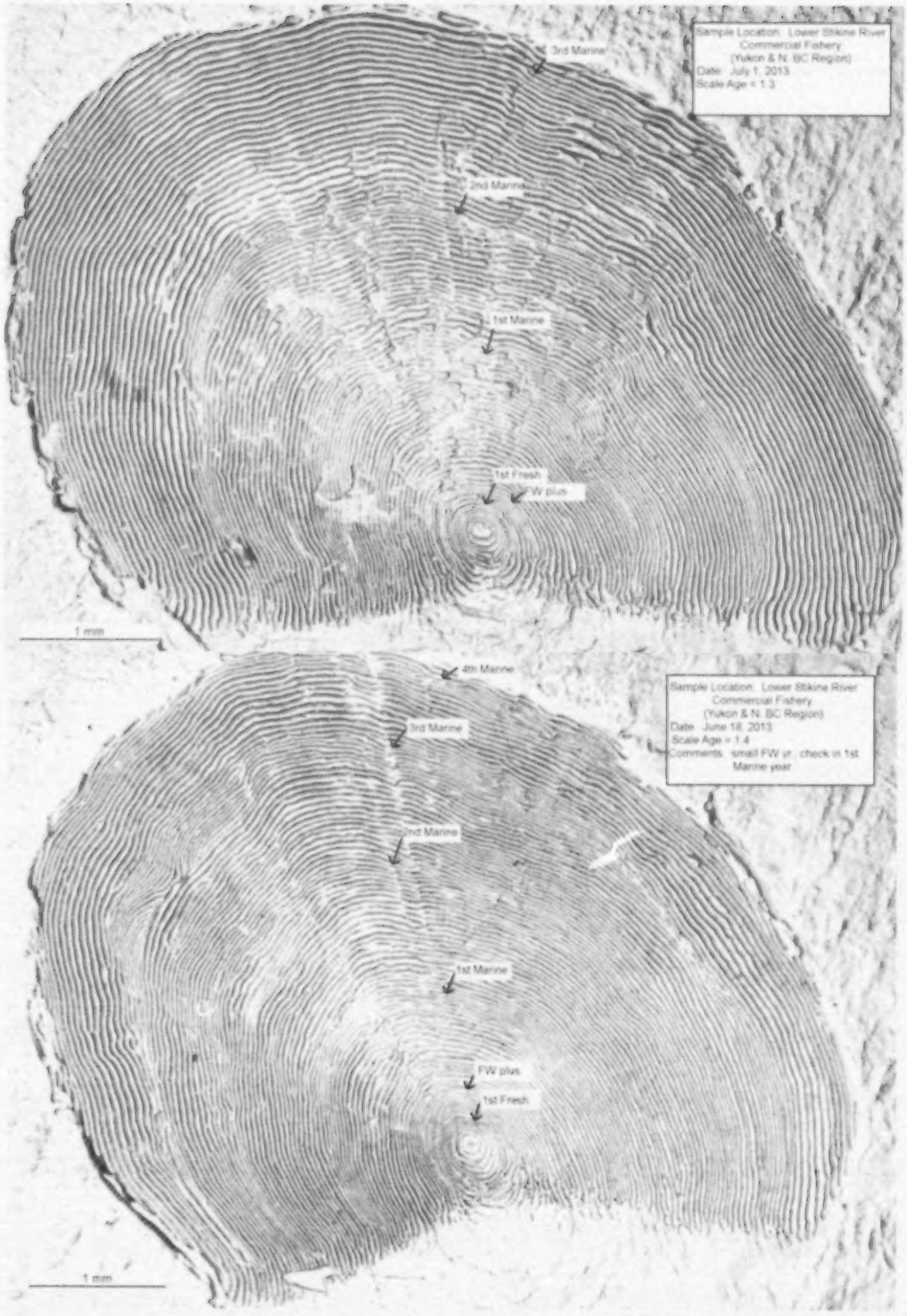
Sample Location: Skeena River Test Fishery
Date: June 23, 2013
Scale Age: 2.3
3rd Marine
2nd Marine
1st Marine
2nd Fresh
1st Fresh
1 mm
Sample Location: Nass River (BC North coast)
Date: July 1, 2013
Scale Age = 1.2
2nd Marine (vague)
1st Marine
1st Fresh
1 mm

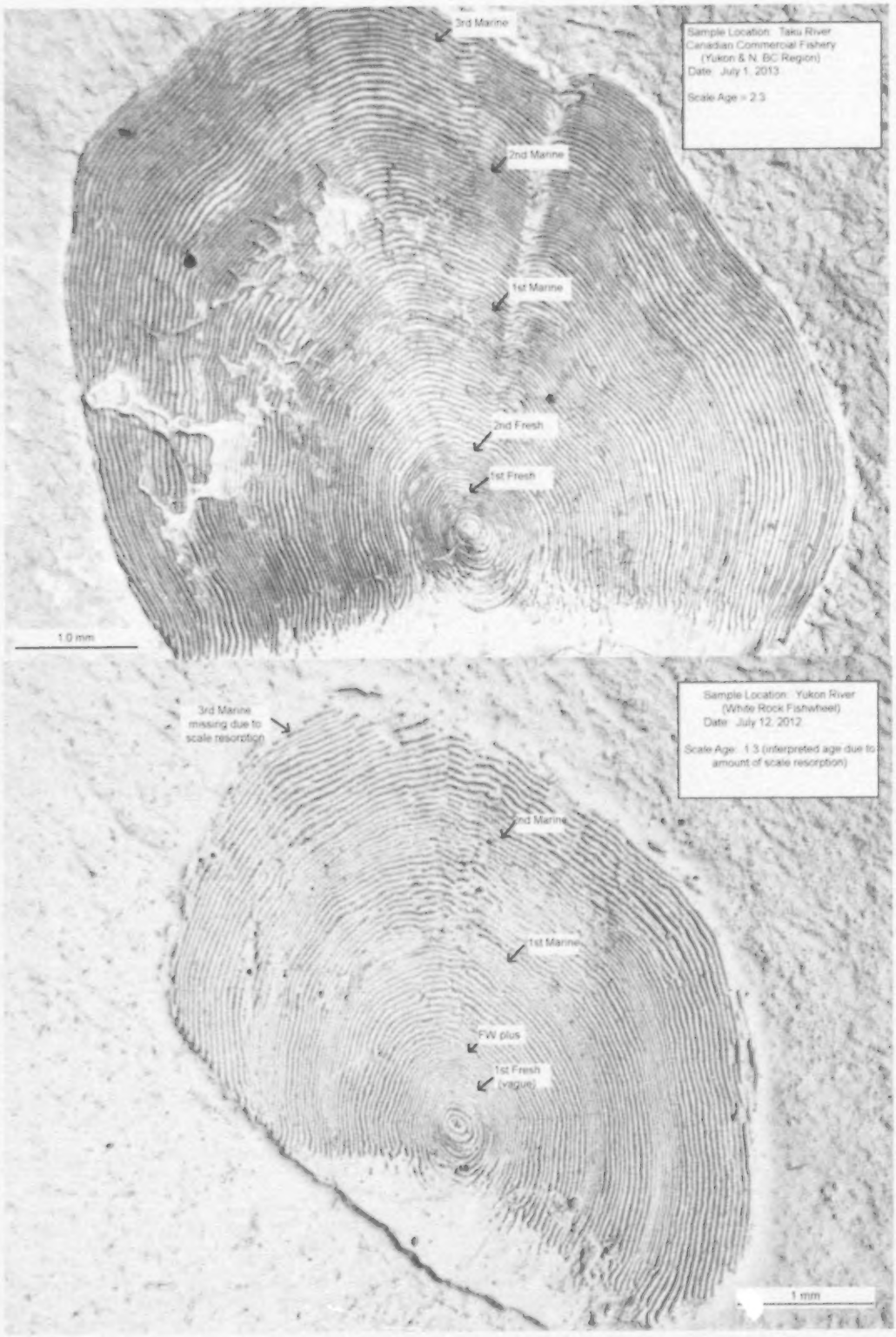

Sample Location: Nass River
(BC North coast)
Date: July 1, 2013
Scale Age = 1.3
3rd Marine
2nd Marine
1st Marine
1st Fresh
1 mm
Sample Location: Nass River
(BC North coast)
Date: July 1, 2013
Scale Age = 2.3
3rd Marine
2nd Marine
1st Marine
2nd Fresh
1st Fresh
1 mm


Sample Location: Kitsumkalum River
(North BC coast region)
Date: Sept. 17, 2013
Scale Age = 1.3, CWT Age = 1.3
1 mm
3rd Marine
2nd Marine
1st Marine
1st FW Annulus
Sample Location: Kitsumkalum River
(BC North Coast region)
Date: August 23, 2013
Scale Age = 1.4 (resorbed
interpretation)
4th Marine
(interpreted)
3rd Marine
2nd Marine
1st Marine
1st FW
1 mm


Sample Location: Kitsumkalum R.
(BC North Coast region)
Date Sept. 10, 2013
Scale Age = 0.4(resorbed interpretation)
CWT Age = 0.4
4th Marine interpreted on scale edge due to amount of resorption
3rd Marine
2nd Marine
1st Marine
1 mm

Yukon/ Northern BC:




3rd Marine
2nd Marine
1st Marine
2nd Fresh
1st Fresh
1.0 mm
Sample Location: Taku River
Canadian Commercial Fishery
(Yukon & N. BC Region)
Date: July 1, 2013
Scale Age = 2.3
3rd Marine
missing due to
scale resorption
2nd Marine
1st Marine
FW plus
1st Fresh
(vague)
1 mm
Sample Location: Yukon River
(White Rock Fishwheel)
Date: July 12, 2012
Scale Age: 1.3 (interpreted age due to
amount of scale resorption)

Appendix 2

Salmon Age Data Sheet Recording Conventions

The conventions for the salmon age data sheets (Fig. 5) are very complicated because of the complex life histories of various salmon species and because multiple structures are used to produce age for one fish. This usually means multiple scales or perhaps fins or otoliths in addition to scales. One or more bundles of scale books/cards, with header cards, bearing all the same information are considered a sample. They often span more than one day but are from the same location. Individual samples are identified by a project name and by a unique database (SCL's Pacific Age Database - PADS) generated number. The number format denotes calendar year and a sample number starting from one each year, e.g. 2014/0001, 2014/0002.

Much of the salmon age data sheet format is set up for the scale method. The SCL works with and records salmonid ages in the European age designation system (Table 2). The standard January 1st birthday is used to assign age with respect to date caught and the amount and type of growth on the scale margin. As of Jan. 1st all fish become one year older. There is one exception, deadpitch samples (from dead fish) may not be sampled until after Jan. 1st but are assumed to have died in the previous year. This convention is necessary to keep a spawning cohort together for analysis. Precision test results are transferred to the original age data sheet, after the fact, for quality assessment and resolution.

Header information:

Project – project name assigned to samples from specific regional salmon programs (see header card)
Sample # - calendar year and database sample number assigned by PADS (e.g. 2014/0051)
# of Fish – number of fish in the sample
Species – salmon species common name
Format – format used to mount scales onto the scale card grid (e.g. 2A=2 across, 5D=5 down, 5A=5 across, 10A=10 across)
Date caught – date(s) the fish were caught/died, format yyyy mon dd (e.g. 2014 Nov 08), may be a range (e.g. 2014 Sep 23 – Oct 01)
Location – place the sample was collected (e.g. Nass River, Albion Ferry)
Area code – BC statistical area code indicating where the sample was collected (e.g. 29C, 23)
Sample remarks - summarize significant sample issues or observations
Time – 1st reader records the time it took to age the sample through once to nearest 15 minutes
QCt – tester records the time it took to complete the precision test and age any additional fish that were flagged or precision results indicated should be read a 2nd time
QCn – tester adds together and records the number of fish aged in the precision test plus any additional fish aged a 2nd time aside from the precision test

Precision results:
Precision results - record which structures were tested (e.g. scales, fins, otoliths).
n – number of fish in precision test
vs - record the reader ID's involved in precision test, tester vs 1st reader (e.g. PK vs RD)
% Agreement - record percent agreement between tester and 1st reader

Fish information (far left of working columns):

- MMDD - Month and day sampled (in numerals), fill in both columns for date ranges
- Book # - scale book number (for scale samples only)
- Fish # - individual fish numbers within each book (e.g. 1-5, 1-10, 1-25 or 1-50)

Resolved age columns (left of working columns):

- Final age – input age type resolved ages from multiple methods (e.g. otoliths and scales)
- Fin age – input final resolved fin age
- Otolith age – input final resolved otolith age
- Resorbed?* – record a check to indicate that resorption is occurring on otoliths
- Scale age – input final resolved scale age type
- Edge** – record code indicating whether scale resorption has affected age
- Part-age comments*** - record codes to indicate cause for scale part-age, e.g. RG, Wet, etc.

* ** *** See Codes section below

Working columns:

Each working column "group" includes a header and columns for age and edge growth. Label working column headers in order of: method (e.g. scale 1, scale 2, otolith surface, fin xs), date the sample was aged (yyyy mon dd) and reader ID initials (e.g. RJ, TM).
The ages in these columns reflect only the number of annuli present/visible on the structure. Age class is interpreted later based on edge growth amount, presence of resorption, time of year caught and the January 1st birthdate from all structures aged for each fish and then recorded in the otolith, fin, scale and/or final resolved age columns.

Age is recorded using the European age designation system (e.g. 1.2, 0.3). Multiple scales are usually collected for each salmon. The general rule is that a reader should review and record the age of at least two scales/fish to assess age class accurately. It may be necessary to review more than two or all scales if resorption or ambiguous fresh/saltwater growth zones are issues. Different scales may present slightly different information. Each age data cell in the working columns may contain multiple pieces of information besides age, e.g. scale condition codes. When either fresh or saltwater age cannot be assessed a part age should be recorded in the working column cell, e.g.

M2=2 marine annuli, no freshwater age or 1F=1 freshwater annulus, no marine age. Part ages can be of some use to clients. A number of codes have been developed to provide information about scale pattern or sampler problems and must be included in the same cell with the age, e.g. M2 W or M3 RG. The part-age codes will be transferred to accompany the age class. The most common codes used for part-age describe scales that are regenerate (RG), wet (W), resorbed (RS), damaged (DM), taken from the lateral line (LL), are non-preferred (NP) or poorly pressed (PP). If no age can be estimated due to scale condition record a code(s) to explain the lack of an age, e.g. W, RG, NS. This information can provide valuable feedback to clients to help improve sample quality issues.

Each working column group includes a growth column. This column records an edge growth code for each age. The amount of edge growth influences the age class interpretation. In the case of scales, resorption affects the reader's ability to make that assessment. Scale growth codes *** express how much scale margin growth was present after the last annulus and indicate if resorption and/or time of year caught affected the assignment of the age class in the resolved age column. The codes represent an objective relative measurement that describes how "complete" the last annual growth zone is relative to the previous year's growth. Rough measurements are done by eye.

To speed up recording information for multiple scales per fish a short hand was developed to record information in the working columns:

- Arrow - indicates same age/circumstance as previous cell(s)
- Dot– means the scale was examined but provided no new information from any of the previous cells
- Blank cell - reader decided it was unnecessary to look at all scales

Codes:

<u>* Scale condition codes:</u>

- 2F = 2 freshwater annuli with unknown number of saltwater annuli (usually due to resorption)
- CE = clean edge (little to no resorption evident on the scale margin, a smooth edge)
- DM = damaged (scale is ripped or missing parts)
- DSA = distinct 2nd saltwater annulus
- DS = double scales in one scale book cell
- FWA = freshwater annulus
- LL = lateral line scale (scale has a hole/groove and distorted growth in the centre)
- M2 = unknown number of freshwater annuli (usually regenerate or wet) with 2 saltwater annuli
- MF = mixed fish (scales taken from 2 different fish)

- NA = no age (readers/readings from different structures could not agree on either FW or SW age)
- NS = no structure (missing scales, otoliths or fins)
- NP = non-preferred scale (scale pattern may be miss-shaped, distorted or missing growth because it was taken from a non-preferred location on the body)
- PC = prominent check
- PP = poor pressing (pressing too "light" to discern pattern clearly)
- RG = regenerate scale (scale centre is missing, therefore blank)
- RS = resorbed scale (growth from scale margin is missing from scale surface)
- SWA = saltwater annulus
- W = wet scale (scales were mounted onto gummed card with too much water, glue has filled in scale ridges resulting in blank featureless areas on the scale impression)
- TC = transition check (growth stress indicating a movement from fresh to saltwater)
- UD = upside-down (scale has been mounted with smooth side up)
- UF = Unresolved number of freshwater annuli (readers cannot decide on freshwater age)
- UM = Unresolved number of marine annuli (readers cannot decide on a marine age)
- VSA = vague 2nd SWA

** Edge codes for scales:

- blank = no resorption
- 0 = resorption present, but not affecting age
- 1 = resorption has eroded past the last annulus and it is assessed that one year should be added to the "visible" age of the scale
- 2 = the scale is resorbed to an extent such that it cannot be determined if any number of annuli are missing from the scale margin
- 3 = one year added to visible age due to date fish was caught (e.g. January – June)
- 4 = one year added to visible age due to date fish was caught and the scale is slightly resorbed, but not affecting age

***Codes describing relative growth size of last annual zone on scale margin:

- 1= less than ¼ previous year (1-2 circuli)
- 1^2 = about ¼ previous year
- 2^1 = just short of ½ of previous year
- 2 = about half the width of previous year
- 2^3 = a little more than ½ of previous year
- 3^2 = just short of previous year
- 3 = same as previous year
- 3^+ = more than previous year

Precision columns:

There are two columns for precision test results in case more than one structure is used to age the sample. As for the working columns, record method, date aged & reader ID in column headers. Transfer the age class from the precision sheets to the precision columns for comparison against the age class recorded in the final/otolith/fin/scale resolved age columns. Do not transfer edge growth codes from the precision sheets; rather use the cell beside the age class to mark an X to flag disagreement with the first reader's age class.

Comments column:

The comments column contains remarks regarding the quality of the structures, problems generating an age or perhaps other possible ages. Comments can include codes listed above, otherwise words must be written out in full.